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RESOLUTION OF A FEW METRES
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EPE EVERYDAY PRACTICAL ELECTRONICS

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Our December 2014 issue will be published on Thursday 06 November 2014, see page 72 for details.

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

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We can supply back issues of *EPE* by post, most issues from the past five years are available. An *EPE* index for the last five years is also available at **www.epemag.com**. Where we are unable to provide a back issue a photocopy of any one article (or one part of a series) can be purchased for the same price. Issues from Jan. 99 are available on CD-ROM or DVD-ROM – and back issues from recent years are also available to download from **www.epemag.com**. Please make sure all components are still available before commencing any project from a back-dated issue.

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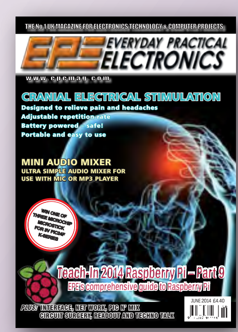

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SEPT '13

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FEATURES • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 2

OCT '13

PROJECTS • LED Musicolour – Part 1 • High-Temperature Thermometer/Thermostat • Ingenuity Unlimited

FEATURES • Teach-In 2014 – Part 1 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 3

NOV '13

PROJECTS • CLASSiC-D Amplifier – Part 1 • LED Musicolour – Part 2 • Mains Timer For Fans Or Lights • Ingenuity Unlimited

FEATURES • Teach-In 2014 – Part 2 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

DEC '13

PROJECTS • Six Test Instruments In One Tiny Box • Virtins Technology Multi-Instrument 3.2 • CLASSiC-D Amplifier – Part 2 •

FEATURES • Teach-In 2014 – Part 3 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work

JAN '14

PROJECTS • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 1 • The Champion Amplifier • Simple 1.5A Switching Regulator •

FEATURES • Teach-In 2014 – Part 4 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

FEB '14

PROJECTS • High-energy Electronic Ignition System – Part 1 • Mobile Phone Loud Ringer! • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 2

FEATURES • Teach-In 2014 – Part 5 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

MAR '14

PROJECTS • Infrasound Detector • Extremely Accurate GPS 1pps Timebase For A Frequency Counter • High-energy Electronic Ignition System – Part 2 • Automatic Points Controller For Your Model Railway Layout

FEATURES • Teach-In 2014 – Part 6 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

APR '14

PROJECTS • Jacobs Ladder • Deluxe GPS 1pps Timebase For Frequency Counters • Capacitor Discharge Unit For Twin-Coil Points Motors

FEATURES • Teach-In 2014 – Part 7 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work • Beta-Layout's Re-Flow Oven Kit And Controller review

MAY '14

PROJECTS • Rugged Battery Charger • CLASSiC-D ±35V DC-DC Converter • Digital Multimeter Auto Power-Down • Control Relays Over The Internet With Arduino

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JUNE '14

PROJECTS • Cranial Electrical Stimulation Unit • Mini Audio Mixer • Adding Voltage And Current Meters To The Bits 'N' Pieces Battery Charger •

FEATURES • Teach-In 2014 – Part 9 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • PIC N' Mix • Net Work •

JULY '14

PROJECTS • Versatile 10-Channel Remote Control Receiver • Li'l Pulser Model Train Controller • Two Demonstration Circuits For Human Colour Vision •

FEATURES • Teach-In 2014 – Part 10 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • PIC N' Mix • Net Work • Audio Out •

AUG '14

PROJECTS • Active RF Detector Probe For DMMs • Add A UHF Link To A Universal Remote Control • PCBirdies • USB Port Voltage Checker • iPod Charger Adaptor •

FEATURES • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • PIC N' Mix • Net Work • Audio Out •

SEPT '14

PROJECTS • Build An AM Radio • LED Ladybird • Lifesaver For Lithium or SLA Batteries • 'Do Not Disturb!' Phone Timer •

FEATURES • Make Your Own PCBs – Part 1 • Techno Talk • Practically Speaking • Circuit Surgery • PIC N' Mix • Net Work • Audio Out • Max's Cool Beans •

OCT '14

PROJECTS • SiDRADIO: An Integrated SDR Using A DVB-T Dongle – Part 1 • Hi-Fi Stereo Headphone Amplifier – Part 1 • "Tiny Tim" Horn-Loaded Speaker System •

FEATURES • Make Your Own PCBs – Part 2 • Techno Talk • Interface • Circuit Surgery • PIC N' Mix • Net Work • Audio Out • Max's Cool Beans •

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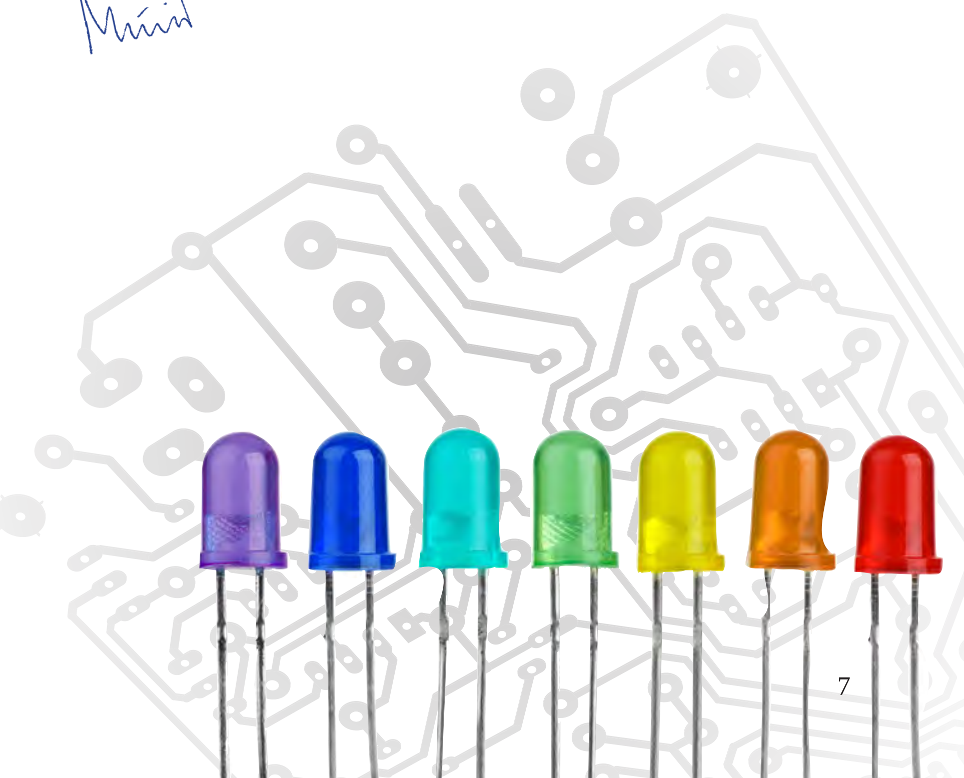
EVERYDAY PRACTICAL ELECTRONICS

Happy birthday to us!

Doubtless you'll have guessed by now that this is no ordinary birthday issue. *Practical Electronics* – the original incarnation of *EPE* – is 50! So it is very much a case of 'Happy birthday to us', and by 'us' I mean not only those who contribute directly to the magazine, but also those who support, subscribe and read it. Without our loyal readership *EPE* would have gone the way of so many other electronics magazines and become just another depressing footnote in publishing history. Fortunately, *EPE* is different; we have weathered the storms, flourished and survived. As editor, I am very pleased to report in our golden anniversary issue that *EPE* is in fine health and ready for the next half century.

Net Work columnist Alan Winstanley has produced an excellent and detailed write up of *EPE's* fascinating history – Part 1 in this issue, to be followed by the concluding half next month. I am sure you will find it an absorbing read. Perhaps you remember constructing some of the early projects Alan mentions. If so, do you still have them, and are they still working? We would very much like to hear from you if you have amusing or interesting anecdotes from the early days of *Practical Electronics*. Did you pen an early article, write a letter or help *PE/EPE* in some other way. Whatever your contribution, drop us a line and tell us your *EPE* story.

I cannot thank everyone who has helped *EPE* to be the success it has been and still is today – there have been just too many fine contributors – but let's have a round of applause for Fred Bennet, Mike Kenward, Dave Barrington and John Becker. It has been my great pleasure to work with all of them except original editor Fred, and I look forward to many more years of exciting work at *EPE* with the current enthusiastic team at Wimborne Publishing.



NEWS

A roundup of the latest Everyday News from the world of electronics

Lights out for LightScribe – report by Barry Fox

Technology that is launched and promoted with vigour often dies silently, to save face for the company behind it. HP's LightScribe is a classic example.

Lightscribe

The LightScribe system was introduced in 2004 to let LightScribe-enabled PC drives use the drive laser to burn high resolution text and graphics into the optically sensitive label surfaces of LightScribe blanks.

It was a clever system that could produce professional-looking labels, albeit in only one colour. HP's PCs routinely came with LightScribe drives and Verbatim gave the system strong support with a wide range of Lightscribe-coated blank DVDs and CDs. But attempts at making LS drives burn multi-coloured labels, with multiple dye layers, failed; the way the Blu-ray system allocates free space on the disc surface blocked the design of BD blanks.

Still available?

Googling HP's LightScribe website (**www.lightscribe.com**) still promises that 'with LightScribe; you just burn your data; flip the disc; then burn your label'. However, the site home page now carries the notice: 'Thank you for your interest in the LightScribe disc labelling technology. This website is no longer active. LightScribe software and disc utilities may be found on a number of public websites.'

When I tried to download LightScribe software and disc utilities from one of the (normally safe and reliable) public websites referred to by HP, the process heavily infected my PC with malware, which diverted web searches to various unwanted web sales sites.

Status according to HP

HP seems never to have formally announced a demise, so I asked HP about the current status of LightScribe. A spokeswoman for HP said: 'this service was cancelled in commercial PCs in 2011 but (we) would like to check for the consumer side of the business.'

After checking, the spokeswoman added: 'I can confirm that HP desktops no longer support LightScribe, due to an industry-wide deficit of certain optical disc drive components. In May 2011, HP released the following information on the HP Support Centre: 'Beginning in May 2011, HP LightScribe technology optical disc drives will be at the end of their production life. HP will continue to ship PCs with HP LightScribe technology until the current supply of these optical drives is depleted. After the supply has been depleted, HP will use drives with equivalent features and functionality but without HP LightScribe technology. This will result in some systems shipping with HP LightScribe drives and some without. Eventually, all HP business desktop models will transition to drives without LightScribe technology. The time it takes to transition may vary by model.

'Customers who ordered certain HP PCs containing optical disc drives with HP LightScribe technology will begin receiving systems with optical drives that do not contain HP LightScribe technology. PCs containing optical drives that do not have LightScribe technology will not be able to burn LightScribe labels. For customers using software and drivers provided by HP, there is no impact to their software drivers or image.

End of the line

'I'm afraid this is all the information I've got on LightScribe' the spokesperson added.

So it's a semi-secret RIP for HP's LightScribe.

EPE EVERYDAY PRACTICAL ELECTRONICS

If you have some breaking news you would like to share with our readers, then please email:

editorial@wimborne.co.uk

Williams supplies Formula E battery

Not your average car battery – assembly of Williams' Formula E battery

You know electric cars have truly 'arrived' when the FIA sanctions a series of races – in this case called 'Formula E'. The series was conceived in 2012, and the inaugural championship will be held in 2014/2015. For the first season, all teams have been supplied an electric racing car built by Spark Racing Technology (SRT), called the Spark-Renault SRT 01E. The chassis has been designed by Dallara, with an electric motor developed by McLaren (the same as that used in its P1 supercar), driving the whole system is a battery system created by Williams Advanced Engineering (WAE).

Electric parameters

The complex battery had to meet the requirements of FIA regulations and SRT Formula E racing car requirements: 200kg cell weight limit, 1000V maximum allowed bus voltage, 200kW peak power limit and maximum usable energy of 30kWh (including regenerative energy). (Recently, FIA regulations have been updated limiting battery usable energy to 28kWh and allowing regenerative energy free with a fixed FIA regenerative braking efficiency.)

Safety

SRT Formula E car requirements meant that the WAE battery had to be designed into a box, which is called a safety cell, with strictly defined dimensions. The safety cell had been designed in collaboration with Dallara, with the safety cell being the structural part of the car. The safety cell also includes thermal protection and electrical isolation layers with an equipotential bonding network in it.

Control

WAE's Formula E battery consists of Li-Polymer-type pouch cells and employs an indirect liquid thermal cooling system. The cell selection process includes an analysis of the voltage range requirements of the electric drive, thermal and performance behaviour analysis under race and qualification load simulations, packaging into the safety cell, and finally cell level tests. The cells are integrated into a modular construction, sandwiched between all relevant thermal, insulation and structural management layers.

Each cell's voltage and temperature are monitored by a cell monitoring unit (CMU) which also includes hardware for passive balancing. CMUs report their measured parameters to the battery management system, which controls all critical parameters of the battery, such as charge/discharge power limit estimations, cell balancing, contactor controls, isolation monitoring and derating strategies.

SD reaches half a terabyte

SanDisk, a global leader in Flash storage, has launched a 512GB SD card – the SanDisk Extreme PRO SDXC UHS-I memory card. The new offering is designed to meet the demands of industry professionals who require the most advanced gear available for shooting 4K Ultra High Definition (3840×2160p) video, Full HD video (1920×1080) and high-speed burst mode photography.

Since SanDisk unveiled its first 512MB SD card in 2003, capacity demands have increased enormously and the new 512GB SanDisk Extreme PRO SDXC UHS-I card represents a 1,000-fold capacity increase in just over a decade, yet maintains the same size footprint. The 512GB card provides write speeds up to 90MB/s, delivering both the speed and capacity needed to support 4K Ultra HD video capture.

Enigma – British Museum's 100 objects to teach history

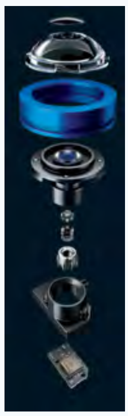
A rare Enigma machine on display at Bletchley Park has been chosen by The British Museum as one of 100 objects to help teach history to children. Enigma is perhaps the best-known cipher machine of all time and is inextricably linked with the ground-breaking work and achievements of Bletchley Park during World War Two. The Enigma is on display at Bletchley Park, among the largest collection of Enigma machines in Europe. The significance of Engima is that it inspired a burst of technical and creative effort in mathematics and computing that lead directly to the modern computer and communications industries. Further detailas available at: **www.bletchleypark.org.uk**

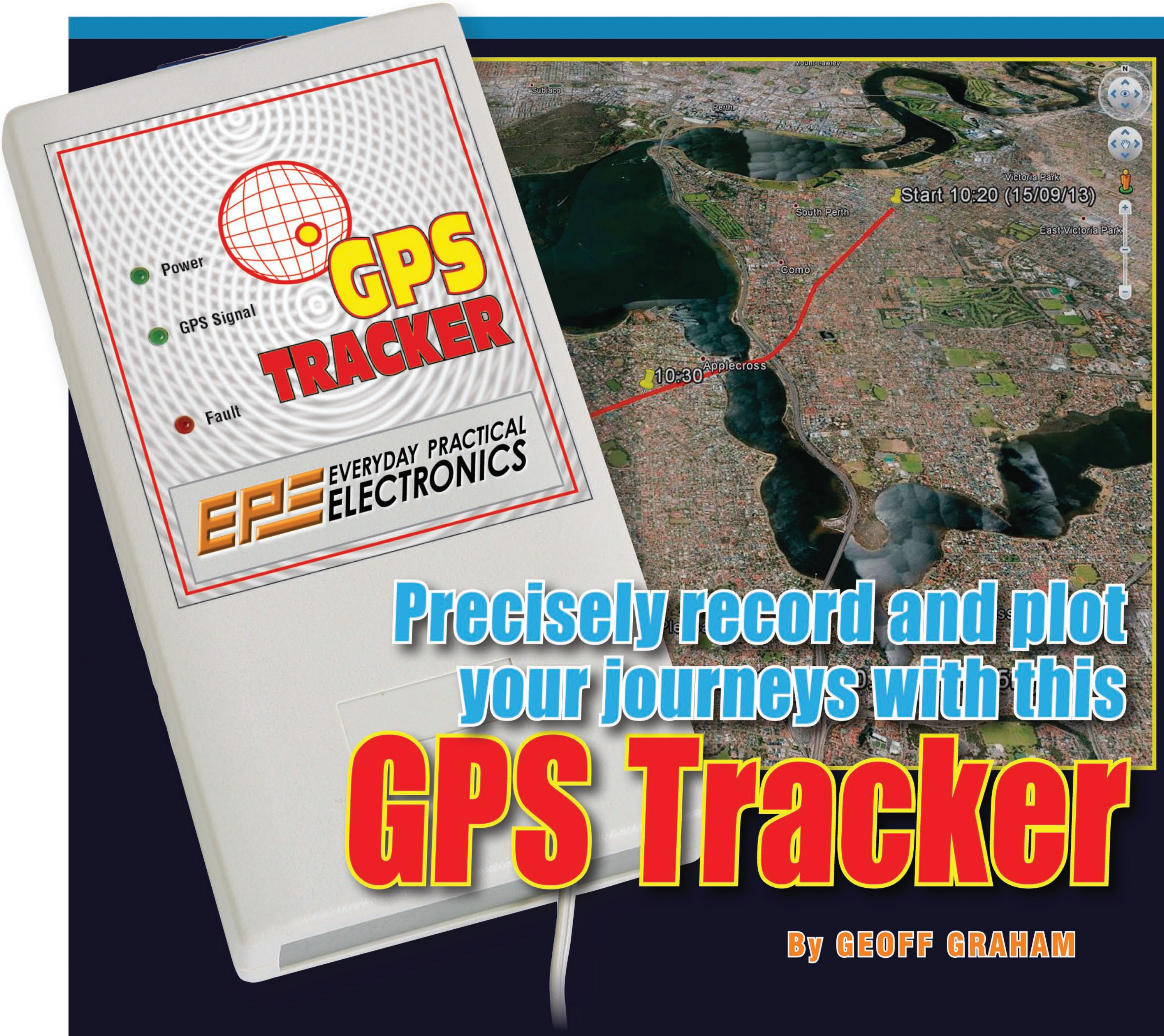
Dyson eyes up robot cleaning

British Engineering company Dyson has launched the Dyson 360 Eye robot vacuum cleaner – the result of 16 years and £28m worth of R&D by a team of more than 200 engineers.

Algebra, probability theory, geometry and trigonometry combine to create the 360 Eye robot's vision of the world. It took over 100,000 hours from a team of 31 software engineers to create the navigation system.

The camera in the Dyson 360 Eye robot vacuum cleaner takes up to 30 frames per second – enabling the machine to effectively interpret its surroundings. Since the shutter speed of the camera matches the machine's speed of travel, its position is always accurate to within millimetres, so it knows exactly where it is in the room, where it is yet to clean and uses infrared sensors to detect where obstacles lie.

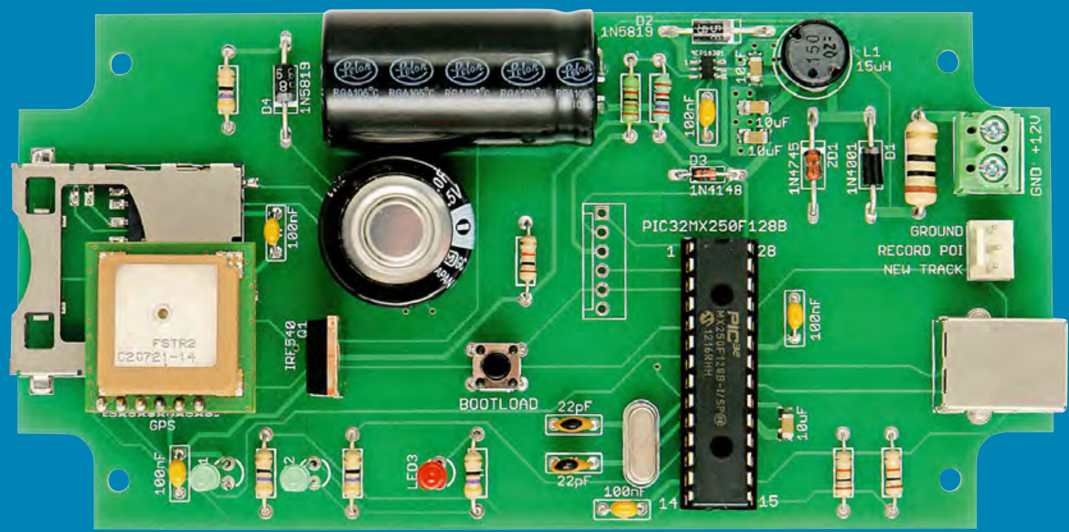




Precisely record and plot your journeys with this GPS Tracker

By GEOFF GRAHAM

This little gadget will precisely record where your car, boat or plane has travelled over time. Using software such as Google Earth you can see your trips mapped onto the surface of the Earth with a resolution of just a few metres. It's a great device for off-road drivers, sailors, farmers and nomads, and can record a lifetime of travel onto a single SD card.



All the parts mount on a single PCB. The GPS module can be seen sitting over the SD card socket on the left, the power supply is on the top right of the board and at the far right are the connectors for power, the optional inputs and the USB socket.

THIS PROJECT was originally created for a couple who were going to do the 'grey nomad' trek anticlockwise around Australia in a 4WD and caravan. Why anticlockwise? Because it's shorter, as you are driving on the left side of the road and on the inside of a circle!

During their journey, they wanted a foolproof method of recording their route without the complications of keeping a log or constantly running a laptop computer with a GPS dongle. This *GPS Tracker* is the result.

Basically, it's a small box that can be wired to the vehicle's ignition and then forgotten. Each time the vehicle is used, the *GPS Tracker* automatically records the time, date and the route taken on its SD card. This SD card can be removed later and inserted into a computer so that the stored history can be displayed in Google Earth or some other mapping software.

If you are not a grey nomad, this device can be used for many other tasks – from farmers wanting to know which paddock they ploughed (and when) to boat users or fishermen who would like to know where they have been in the past. It could even be installed in the family car – imagine being able to see precisely the route taken on a particular day some time in the past.

But there's more! The *GPS Tracker* can also record points of interest (POI) and automatically build a spreadsheet that records a diary of your vehicle's business and private use in a format that (hopefully) not even the tax department could argue with.

A lifetime of detailed travel data can be recorded on a single standard SD card, so the entire history of a vehicle could be recorded for posterity. This data could be useful at some time in the future, especially for a business vehicle.

Main features

- Records the route, time and date on an SD card each time the vehicle is used.
- Stored SD card data displayed in Google Earth or other mapping software.
- Records points of interest (POI) at the press off a button. In Google Earth, each POI marker is displayed as a yellow pin with an associated time and distance from the start.
- Record formats: Google Earth KML, GPS Exchange, raw NMEA data and two Microsoft-Excel-compatible formats.
- Can record POI locations in a spreadsheet called LOG.XLS and record a travel diary with private and business entries in a spreadsheet called DIARY.XLS.
- When diary recording is turned on, pressing POI button during a trip means the distance travelled (in km) is recorded in 'Business' column of DIARY.XLS.
- Powered from vehicle's 12V battery and can be permanently wired into circuit.

File formats

The *GPS Tracker* can record data in five different formats: Google Earth KML, GPS Exchange, raw NMEA data and two Microsoft Excel-compatible formats.

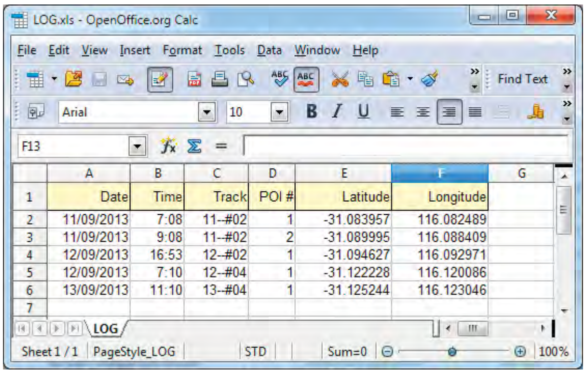
The Google Earth formatted file has the extension '.KML'. If you have Google Earth installed on your computer (PC, Mac, or Linux) you only need to double click on the file and it will automatically open in Google Earth and display the track, with markers showing the start, end and points of interest (POI).

Google Earth is free and has many features that assist in displaying your track. These include the ability to zoom in and see detail, combine many separate trips into one overall view and turn visual features on and off.

The second file format is the GPS Exchange Format (ie, file extension .GPX). This is an open XML data format for the interchange of GPS data (waypoints, routes, and tracks) between applications. Many open applications available on the Internet use this format.

Google Earth also supports this format, but its main use is with software that can automatically work out where you have taken photographs and insert the latitude and longitude into the EXIF data area of the photographs. The software does this by comparing the date and time that your photograph was taken with the date and time in the *GPX* format file.

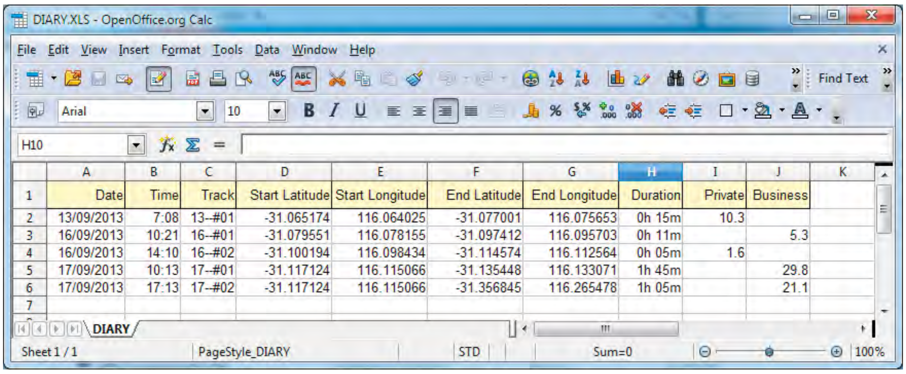
The third file format supported is the raw NMEA (National Maritime Electronics Association) 0183 data which is stored in a file with a .TXT



LOG.xls - OpenOffice.org Calc

	Date	Time	Track	POI #	Latitude	Longitude
2	11/09/2013	7:08	11--#02	1	-31.083957	116.082489
3	11/09/2013	9:08	11--#02	2	-31.089995	116.088409
4	12/09/2013	16:53	12--#02	1	-31.094627	116.092971
5	12/09/2013	7:10	12--#04	1	-31.122228	116.120086
6	13/09/2013	11:10	13--#04	1	-31.125244	116.123046

Fig.1: the *GPS Tracker* can be configured to record POI (point of interest) locations in a spreadsheet called LOG.XLS which makes them easy to reference later on.



DIARY.XLS - OpenOffice.org Calc

	Date	Time	Track	Start Latitude	Start Longitude	End Latitude	End Longitude	Duration	Private	Business
2	13/09/2013	7:08	13--#01	-31.065174	116.064025	-31.077001	116.075653	0h 15m	10.3	
3	16/09/2013	10:21	16--#01	-31.079551	116.078155	-31.097412	116.095703	0h 11m		5.3
4	16/09/2013	14:10	16--#02	-31.100194	116.098434	-31.114574	116.112564	0h 05m	1.6	
5	17/09/2013	10:13	17--#01	-31.117124	116.115066	-31.135448	116.133071	1h 45m		29.8
6	17/09/2013	17:13	17--#02	-31.117124	116.115066	-31.356845	116.265478	1h 05m		21.1

Fig.2: for the tax man, the *GPS Tracker* can also be configured to record a travel diary in another spreadsheet called DIARY.XLS. In this mode, a trip is deemed to be for business if the POI button is pressed during the journey.

extension. This consists of the RMC (latitude/longitude co-ordinates) and GGA (GPS fix) data records, as generated by the GPS module. This format is also used by many applications that can process and display GPS data in interesting ways.

You can configure the *GPS Tracker* to record the data in one, two or all three of these formats, with a specified interval between records. By default, the *GPS Tracker* records KML data once every five seconds and GPX data once every minute but this, along with other parameters, can be easily changed (more on that later).

The POI button

As well as recording the track in the three formats listed above, the *GPS Tracker* can also record data in two different Excel spreadsheets based on the POI input. This input would normally be connected to a switch that would short the input to ground when pressed. The switch could be mounted on the lid of the *GPS Tracker* itself or more likely, the dashboard of the vehicle or boat.

Pressing the switch causes up to three actions to be carried out. The first is to insert a marker in the KML track. In Google Earth, this marker is displayed as a yellow pin symbol with an associated time and distance from the start. This could be used, for example, to record the location of a likely camping spot or the place that you dropped your lobster pot.

You can also configure the *GPS Tracker* to record the date, time, latitude and longitude in an Excel spreadsheet (named LOG.XLS) each time the POI button is pressed. This is handy if you want to keep a convenient list of specific locations (see Fig.1).

For example, if you are a farmer driving around your property, you could press the POI button every time you came across a patch of weeds. You could then later print out the spreadsheet and give it to a contractor as a starting list for weed spraying.

Business vs private diary

The second type of spreadsheet file that can be linked to the POI button is a business/private travel diary. As anyone who uses their car for business knows, you have to keep a diary of your business and private use for the tax man. This can be tedious to say the least, but it is necessary so that you can justify the tax deduction.

Diary recording can be turned either on or off, but is off by default. When it is enabled, the data is saved in an Excel spreadsheet called DIARY.XLS (see Fig.2). This spreadsheet includes the date/time of each trip, the start and end latitude/longitude, the trip duration and the total kilometres.

If the POI button is pressed during the trip, the kilometres travelled will be recorded in the business column; otherwise they will be recorded in the private column.

So, all you need do is press the POI button sometime during each business trip and your complete travel diary will be automatically created, ready to be attached to your tax return.

Design

Because of its intended use, the *GPS Tracker* was designed to be as simple and foolproof as possible. As shown in the photos, it's housed in a small ABS case with a power cable (+12V from the vehicle's ignition) feeding in at one end and a slot to insert the SD card at the other. There are also three indicating LEDs on the front panel, and that's it.

The firmware is designed to be as forgiving as possible and will automatically recover from events such as loss of the GPS signal and power failure.

Circuit details

Take a look now at Fig.3, which shows the complete circuit. It consists of three main sections: a microcontroller (IC1), a GPS module and a switching power supply.

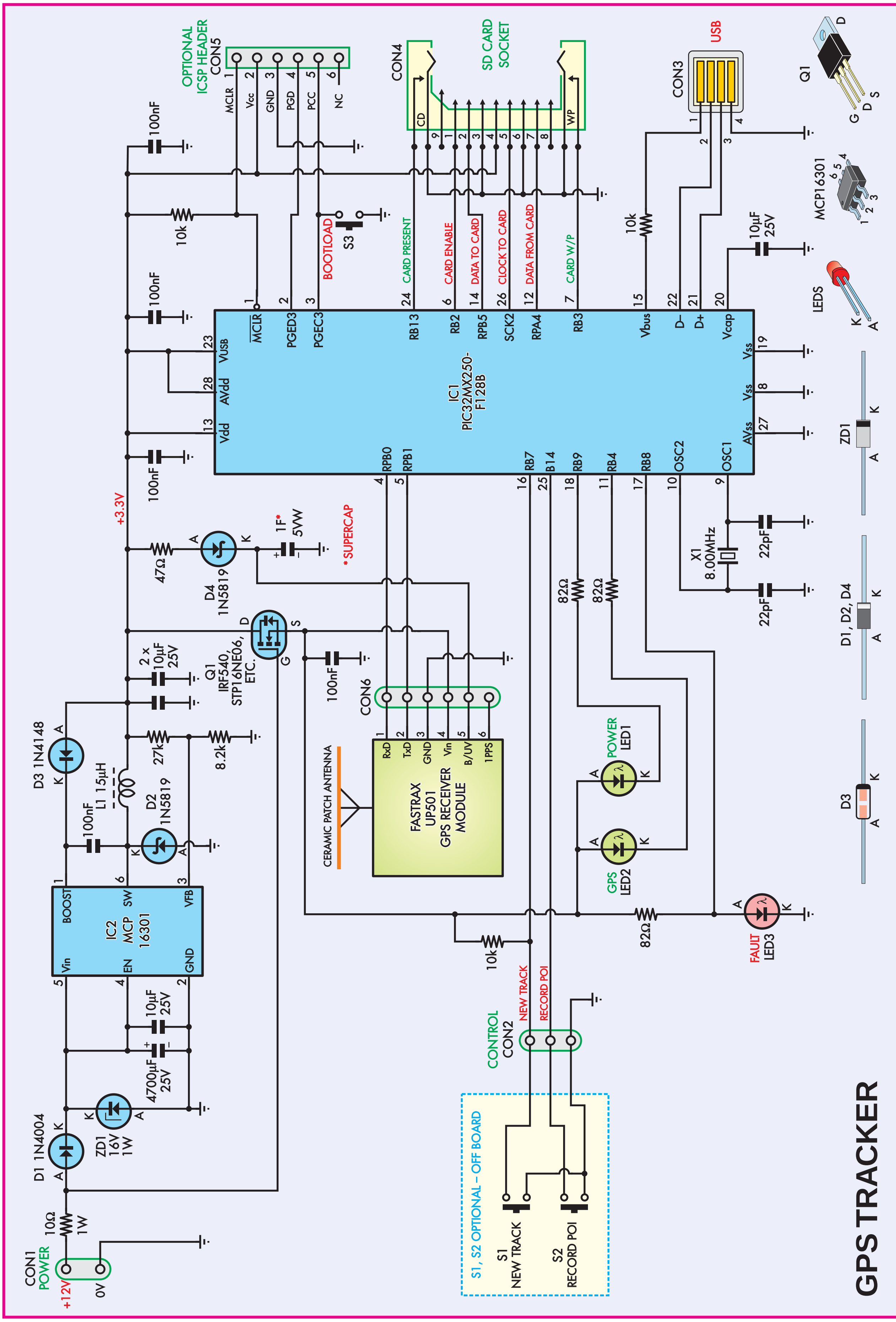
The microcontroller used is a PIC32MX250F128B, the latest variant from the Microchip PIC32 stable. This was chosen because of its performance – it has a 32-bit processor, the clock runs at 40MHz and it has a large integrated Flash memory (128KB).

When you think of it, the microcontroller has quite a heavy workload. Primarily, it must implement a full FAT16 or FAT32 file system on the SD card, with the ability to create subdirectories and navigate through them. It also must be fast enough to close any open files and flush the data to the SD card if the power fails.

But the best features of this high-performance chip are that it is cheap and comes in a standard 28-pin DIP package that can plug into an IC socket.

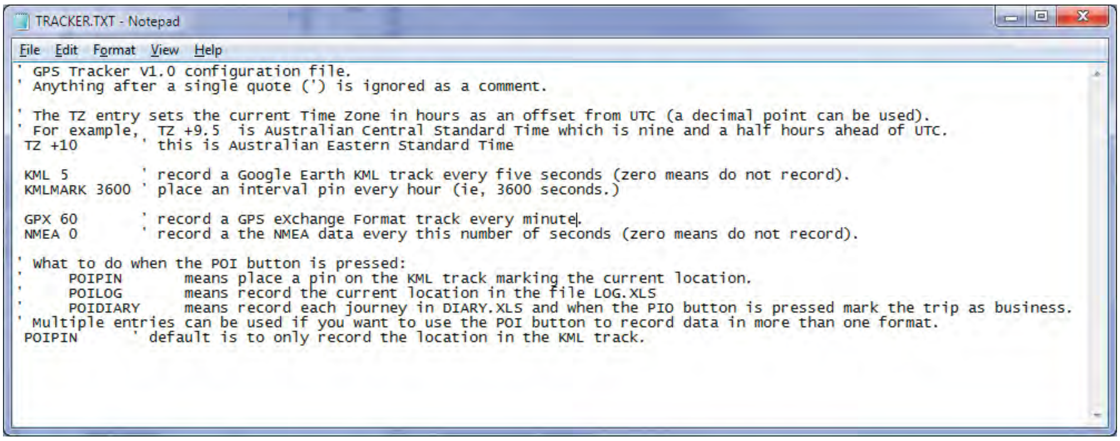
Power supply

The *GPS Tracker* is intended to be powered directly from the vehicle's



GPS TRACKER

Fig.3: the *GPS Tracker* consists of three main sections – a microcontroller (IC1), a power supply (IC2) and a GPS module. The power supply is designed to provide a regulated 3.3V supply for up to two seconds after the 12V supply has been removed.



```
TRACKER.TXT - Notepad
File  Edit  Format  View  Help
' GPS Tracker V1.0 configuration file.
' Anything after a single quote (') is ignored as a comment.

' The TZ entry sets the current Time Zone in hours as an offset from UTC (a decimal point can be used).
' For example,  TZ +9.5  is Australian Central Standard Time which is nine and a half hours ahead of UTC.
TZ +10        ' this is Australian Eastern Standard Time

KML 5         ' record a Google Earth KML track every five seconds (zero means do not record).
KMLMARK 3600  ' place an interval pin every hour (ie, 3600 seconds.)

GPX 60        ' record a GPS eXchange Format track every minute
NMEA 0        ' record a the NMEA data every this number of seconds (zero means do not record).

' What to do when the POI button is pressed:
'     POIPIN       means place a pin on the KML track marking the current location.
'     POILOG       means record the current location in the file LOG.XLS
'     POIDIARY     means record each journey in DIARY.XLS and when the PIO button is pressed mark the trip as business.
' Multiple entries can be used if you want to use the POI button to record data in more than one format.
POIPIN       ' default is to only record the location in the KML track.
```

Fig.4: this is the default configuration file created by the *GPS Tracker* if a blank SD card is used. You can use any ASCII editor (Notepad in this example) to change the settings to your preference.

ignition supply. It can either be hard-wired to the fuse block or it can be powered from a cigarette lighter socket (ie, via a flying lead fitted with a cigarette lighter plug).

In practice, the power supply must protect the microcontroller and the GPS module from spikes and reverse voltage. It must also keep supplying power for a short time after the external supply is removed, to allow data to be written to the SD card. As a result, it's more complicated than a simple 3-terminal regulator circuit.

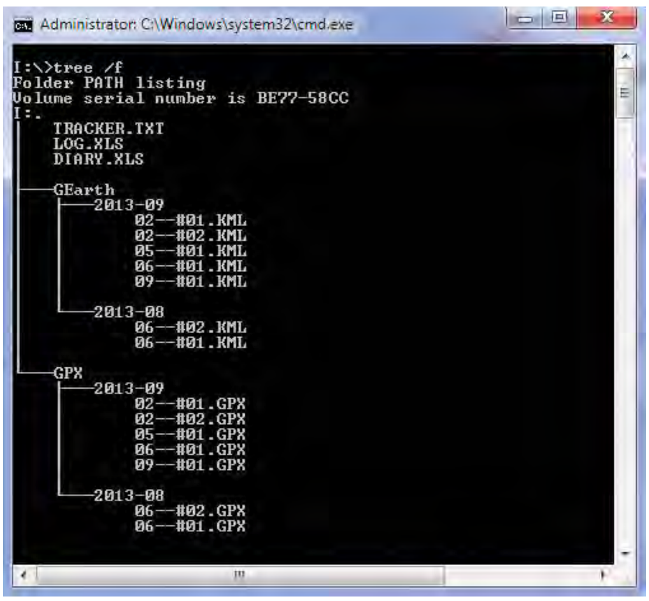
Transient protection is provided by a 10Ω resistor and 16V Zener diode ZD1. These serve to clip any transients while diode D1 (1N4004) provides reverse polarity protection and isolates the main filter capacitor (4700µF) from the vehicle supply when power is removed.

IC2, an MCP16301, is an efficient step-down voltage regulator. This supplies the microcontroller, the GPS module and the SD card with a regulated 3.3V rail. When power is removed, the charge on the 4700µF input capacitor will decay and the regulator will track this falling voltage while still delivering a stable 3.3V output.

In operation, IC2 can keep its 3.3V output stable for almost two seconds after power has been removed.

The microcontroller needs only about 0.3s to flush its data and close the files on the SD card, so using a 4700µF capacitor sounds excessive. However, there's sufficient space on the PCB to accommodate it and using such a high value provides a wide safety margin that will accommodate the inevitable reduction in its capacitance due to heat and aging.

When power is removed from the unit, we need to minimise its current drain so that the 3.3V supply can be maintained for as long as possible. This is achieved by Q1, which immediately disconnects the power to the LEDs and the GPS module (which is not required during shut-down) when the power is removed.



```
Administrator: C:\Windows\system32\cmd.exe
I:\>tree /f
Folder PATH listing
Volume serial number is BE77-58CC
I:.
│   TRACKER.TXT
│   LOG.XLS
│   DIARY.XLS
│
├───GEarth
│   ├───2013-09
│   │       02—#01.KML
│   │       02—#02.KML
│   │       05—#01.KML
│   │       06—#01.KML
│   │       09—#01.KML
│   │
│   └───2013-08
│           06—#02.KML
│           06—#01.KML
│
├───GPX
│   ├───2013-09
│   │       02—#01.GPX
│   │       02—#02.GPX
│   │       05—#01.GPX
│   │       06—#01.GPX
│   │       09—#01.GPX
│   │
│   └───2013-08
│           06—#02.GPX
│           06—#01.GPX
```

Fig.5: this is the directory structure created to hold the data. It consists of three top level directories (GEarth, GPX and NMEA) with sub directories for each month. A file is created within these subdirectories for each trip.

As shown, Q1 is an N-channel MOSFET, which has its gate connected to the supply rail (ie, before reverse polarity protection diode D1). When the ignition is on, this holds Q1's gate at about +9V with respect to its source, and therefore Q1 is turned fully on.

When the ignition is subsequently turned off, Q1's gate voltage immediately falls to zero. As a result, Q1 quickly turns off and in turn removes power to the LEDs and the GPS module.

The main requirement of Q1 in this role is that it should have a low drain-source resistance when turned on. There are many SMD FETs that have this feature, but it is easier to use a commonly-available power FET, even though we are only switching about 50mA.

New track input

When the input power is removed, IC1 detects this on its RB7 input (pin 16) and immediately commences its shut-down routine. This involves terminating the current track and writing the cached data to the SD card.

RB7 of IC1 is also connected to CON2 to provide the 'NEW TRACK' input, but note that a new track is also automatically started if the unit loses power. Shorting this input to ground signals that the current trip has finished. When the short is released, the unit will then start recording a new track.

This facility is provided so that the Tracker can be permanently connected to power if required. The advantage of this is that there will be no delay in it recording the current location, as would otherwise initially occur when power is first applied. Also, because of the efficient power supply design, the *GPS Tracker* only consumes about 50mA and that level of permanent drain is acceptable in a vehicle that's driven regularly.

LEDs 1 and 2 (green) indicate power and correct GPS operation respectively. These are connected between Q1's source and the microcontroller, which pulls its RB9 and RB4 outputs low to turn them on.

LED3 (red) is the fault indicator, and its drive arrangement is a little different. As shown, it's connected between the RB8 output and ground. Normally, the microcontroller turns LED3 off by pulling its RB8 output low, which shorts out the LED. This means that the LED is off as long as the microcontroller is working normally. However, if anything goes wrong with the microcontroller, the LED turns on to indicate a fault.

The firmware also monitors other components such as the GPS module and the SD card, and if anything is wrong, it will turn on the fault LED. That way, the user is immediately warned that data is not being recorded – important in a device that is supposed to work automatically.

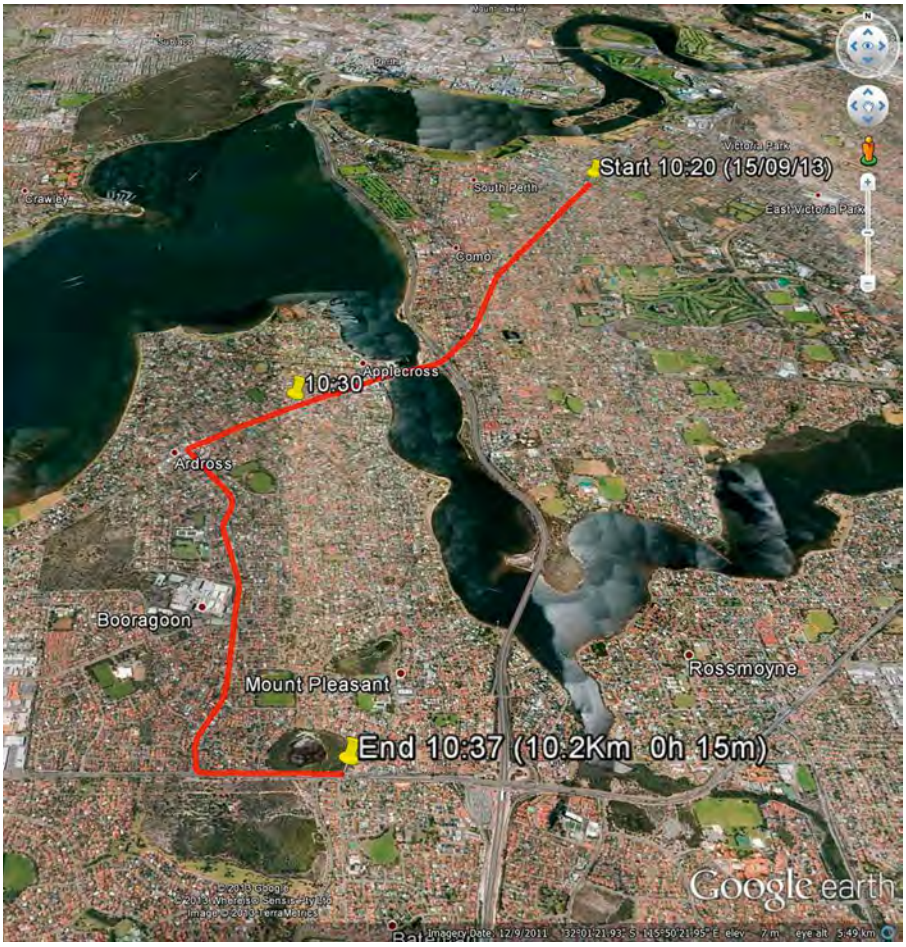
GPS module

The *GPS Tracker* is primarily designed for use with the UP501 GPS module from the Finnish company Fastrax. This amazingly small module is cheap, available from many sources and plugs neatly into the PCB. However, if you want to use an alternative, the firmware will also work with the Globalsat EM-408 module that's been used in many of our projects in the past.

The advantage of the EM-408 is that it is a little more sensitive and it has an MMCX connector for attaching an external antenna. However, it is more expensive than the UP501 and is difficult to mount securely inside the case.

The UP501 needs a back-up supply to keep the internal memory of the module alive when power is removed. This is important because it can take a long time for the module to get all the data it needs from the GPS satellites. Provided the back-up supply is maintained above 2V, the module will remember this information and can get a fix on the satellites and your location more quickly.

Therefore, a one-farad supercapacitor has been included to keep the module's memory alive for up to a week. As shown on Fig.1, this is connected between the GPS receiver's V_{DD_B} pin (pin 5) and ground. On the other hand, the EM-408 has an internal super-capacitor, so the external super-capacitor, diode D5 and the associated 47Ω resistor can be omitted if this module is used.



A typical track as displayed in Google Earth. You can zoom in to see the detail of the track or you can zoom out as in this image to see the whole route. The start marker records the start time and date, while the end marker records the end time, the distance travelled and the duration of the trip.

USB port and ICSP

IC1 provides a USB port at pins 15, 22 and 21 (Vbus, D– and D+ respectively). This is used only for debugging, as discussed later.

The PCB layout also has provision for an ICSP (in-circuit serial programming) connector (CON5) which is not normally fitted. However, if you purchase a blank microcontroller, you can fit this connector and use a programmer such as Microchip's PICkit 3 to program the chip in circuit.

Configuring the tracker

When the *GPS Tracker* starts up, the first thing the firmware does is read its configuration settings from a file called 'Tracker.txt' in the root directory of the SD card. If that file is not found the firmware will automatically create it using its default settings.

Fig.4 shows the typical contents of this file and as you can see, the comments make the file reasonably self-explanatory. In fact, the best way to create a custom configuration for the *GPS Tracker* is to insert a blank SD card and let the firmware create the default configuration file. You can then edit that file to suit your preferences.

The main parameter that you might want to change is the time zone that you are operating in. The *GPS Tracker* gets an accurate time from the GPS satellites but it needs to know your time zone so that it can convert the GPS time to local time for time stamping its records.

Another parameter that you might like to adjust is how often the GPS data is recorded on the SD card. This can be independently set for each of the three main data formats (KML, GPX and NMEA) and can be as often as once a second for accurate recording all the way up to many minutes if you want to keep the data files small.

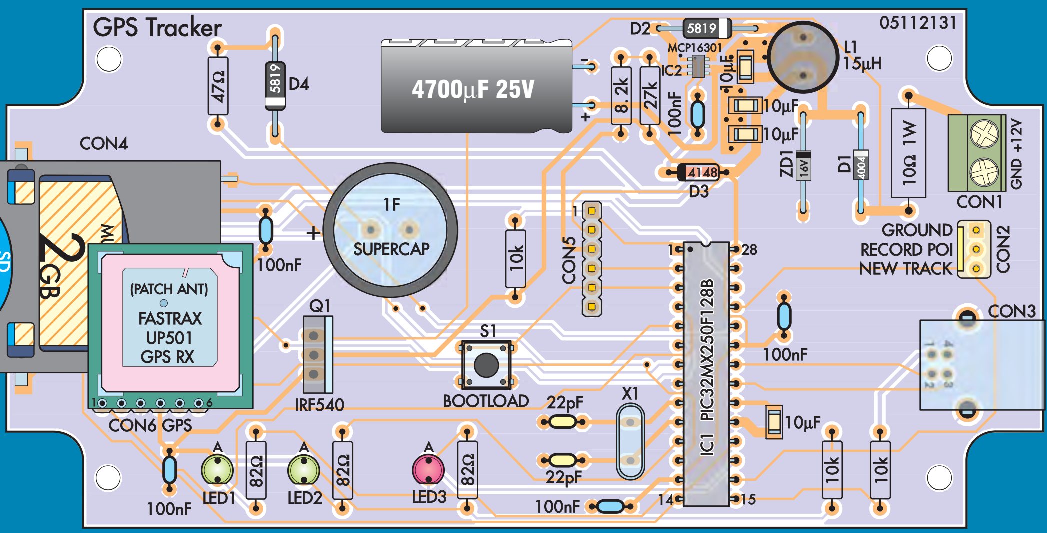


Fig.6: follow this parts layout to build the PCB (note: if you are using the EM-408 GPS module, you can leave out D4, the 47Ω resistor and the supercap). The completed assembly is mounted in the bottom of the case, with the three LEDs at bottom left protruding through holes drilled in the lid.

The KLMARK parameter controls how often (in seconds) a timed marker is placed on the KML track. This can be handy for long trips as it gives you an indication in Google Earth of your progress during the trip. A setting of zero will disable this feature.

The parameters POIPIN, POILOG and POIDIARY are associated with the POI input and don't have an associated value. Just their presence in the configuration file means that that feature will be turned on.

POIPIN means that a marker pin will be placed on the KML track when the POI input is pulled low. POILOG means that the date, time, latitude and longitude of the current location will be recorded in the log file (LOG.XLS) when this happens.

Capacitor Codes

Value	µF Value	IEC Code	EIA Code
10µF	10µF	10u	106
100nF	0.1µF	100n	104
22pF	NA	22p	22

Finally, POIDIARY means each trip will be recorded in a travel diary (DIARY.XLS). If POIDIARY is enabled and the POI input is pulled low at any time during a trip, it will be recorded as a business trip.

Directory structure

Over time, the *GPS Tracker* can accumulate a lot of data, so a directory structure is used to make it easier to locate a particular trip. Fig.5 illustrates this structure.

Starting with a blank SD card, the firmware will create three directories called GEARTH, GPX and NMEA – one for each of the three data formats to be recorded. Within each directory, it will create a subdirectory for each month. The format of the subdirectory name is year-month. For example, the directory '2013-12' will contain the records for December 2013.

Finally, within these subdirectories, each trip will be recorded as a separate file. The file name starts with the day of the month followed by a sequence number for that day. So a file with the name '12--#03.KML' is the third trip recorded on the 12th day of the month.

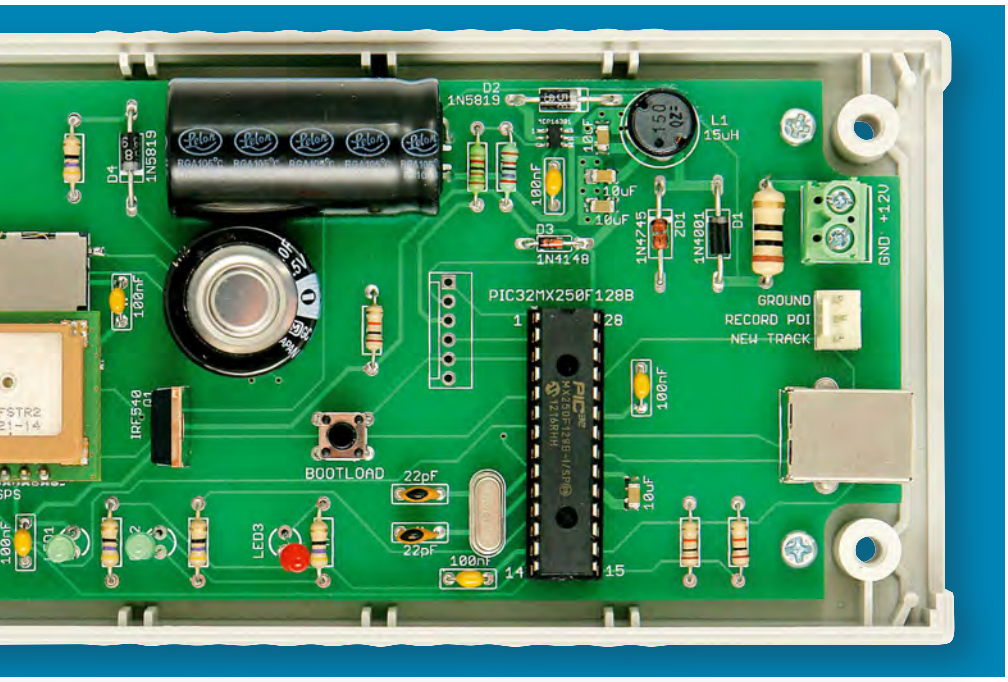
If required, the Excel spreadsheet files (LOG.XLS and DIARY.XLS) will also be created in the root directory of the SD card. They just accumulate data, so if you want to reset them, it's just a matter of deleting them and the firmware then recreates these two .xls files with zero size the next time it starts up.

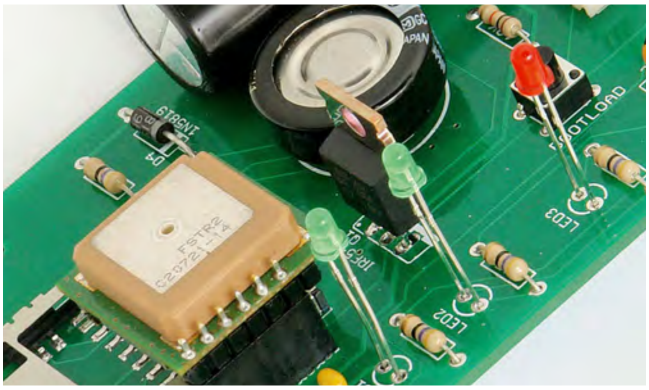
The firmware keeps these and other files open while it's recording a journey. This means that you must not remove the card while it is being used, as that will result in a corrupted file system. Instead, you must always make sure that the power has been removed for a second or two (or the NEWTRACK input pulled low) before removing the card.

The firmware will work with most SD cards up to 32GB in size and formatted with FAT16 or FAT32. Larger cards may also work, but we haven't tested them. However, we expect that larger cards will work if reformatted using the FAT32 file system.

Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	27kΩ	red violet orange brown	red violet black red brown
❏	3	10kΩ	brown black orange brown	brown black black red brown
❏	1	8.2kΩ	grey red red brown	grey red black brown brown
❏	3	82Ω	grey red black brown	grey red black gold brown
❏	1	47Ω	yellow violet black brown	yellow violet black gold brown
❏	1	10Ω	brown black black brown	brown black black gold brown





This close-up view shows how the UP501 GPS module and the three LEDs are mounted. The LEDs must be 20mm proud of the PCB so that they protrude through the case lid.

Typically, a track that is recorded once a second will require about 2MB of storage per 1000km travelled, although this can vary considerably depending on your driving patterns.

These days, an 8GB SD card can be as cheap as £5. So, using 8GB as the benchmark, you will be able to record all three data formats at the rate of once a second for over 1,000,000km. Obviously, storage capacity is not an issue!

Construction

The *GPS Tracker* is built on a double-sided PCB which is available from the *EPE PCB Service*, coded 05112131 and measuring 137mm × 68.5mm. Fig.6 shows the parts layout.

Most of the parts are through-hole devices, so the assembly is fairly straightforward. However, voltage regulator IC2 and the four 10µF capacitors are surface mount devices (SMDs) and these parts must be fitted first.

To mount each SMD, first apply plenty of liquid flux to its PCB pads. That done, place the component in position and hold it down with tweezers or a matchstick while you put some solder on the tip of your iron and tack-solder one pin (or end). Adjust its position by remelting the solder and nudging it slightly if necessary, then solder the remaining pin(s).

Finally, return to the original pin and add more solder, to ensure it is soldered correctly. Don't worry if you get a solder bridge between two pins when soldering IC2. The bridge can be easily removed after the device has been fitted using solder wick.

Note that, for performance reasons, the components around the voltage regulator are closely packed. Check Fig.6 carefully to ensure each device is correctly positioned. **In particular, when fitting IC2, take care to ensure that you identify the faint dot marking pin 1 of the package.**

Once the five SMDs are in place, continue by fitting the remaining parts, starting with the low-profile components (resistors, etc) and then moving on to the taller components. Crystal (X1) should be installed sitting about 2mm above the PCB, so that its metal case doesn't short against the solder pads underneath. This can be easily achieved by pushing the crystal down onto a thick cardboard spacer which is then removed after the leads have been soldered. (Note though that the PCBs supplied by *EPE* should have a solder mask layer over these pads on the top of the board, so in this case the crystal can be pushed all the way down.)

A 28-pin DIL socket is used for microcontroller IC1. Be sure to install it with its notched end positioned as shown on Fig.6.

Fitting the SD card socket

Another part that needs special treatment is the SD card socket which is surface mounted. It has two small plastic posts on the underside that mate with matching holes in the PCB to ensure it is correctly positioned.

In particular, make sure that you find and solder all the SD card socket's solder tabs – there are 16 in total. Two of these are very close together on the front lefthand corner of the socket (viewed from the front) and both should be soldered to the same solder pad.

Other parts

As shown in Fig.6, the 4700µF capacitor is mounted side-on against the PCB. That means that you have to bend its leads down by 90° before fitting it, so that they pass down through the PCB pads. Take care to ensure it is oriented correctly and place a dob of hot-melt glue or neutral-cure silicone under the capacitor before pushing it down into place. This will ensure that it is held against the PCB and prevent it later fracturing its PCB pads due to vibration (the unit is intended for use in a vehicle after all).

LEDs 1-3 are mounted 20mm proud of the PCB, so that they later protrude through their respective front-panel holes. To set the correct height, cut a 20mm-wide strip of thin cardboard and slide it between the legs of each LED while you solder it into position. Make sure the LEDs are all correctly oriented – ie, with their cathode (K) leads towards the edge of the PCB.

This is the level of detail that you can see in Google Earth. The red line is the track of the vehicle and in this case you can even see what traffic lane it was using.

GPS module

The UP501 GPS module plugs into a 6-pin header socket which positions the module over the SD card socket (see Fig.6 and photos). If you are using this GPS module, simply solder a 6-pin header onto the module. It's subsequently plugged into the socket on the PCB after the initial testing.

Alternatively, if you are using the EM-408 GPS module, you need to cut off one of the connectors from the supplied cable and solder the leads to a 6-pin header, as shown in Fig.7. This header is then later plugged into the header socket on the PCB.

As discussed earlier, if you are using the EM-408, you can leave out the super capacitor, diode D4 and the associated 47Ω resistor. However, these parts should be fitted for the UP501.

A problem with the EM-408 is that there's no easy method of mounting it securely. One way around this is to sit the module (with its integrated aerial facing up) on top of a block of soft foam which in turn sits on top of the PCB. Then, when the lid is screwed down, you will have a 'squashed sandwich' arrangement that will push the module against the lid of the box, thereby holding it in place.

Alternatively, you may be able to secure it to the top of the SD card socket using double-sided adhesive foam. Make sure that the adhesive cannot come into contact with the SD card when it is inserted.

The assembled PCB fits neatly into the specified plastic instrument case and is secured at all four corners using short M3 or self-tapping screws. Fig.8 shows the drilling details for the lid (to accept the three LEDs), plus the location of the cut-out required in one of the end panels to accommodate the SD card.

The USB connector is used only for debugging, so there's no need to make a cut-out for it in the opposite end panel. However, you will need to drill a hole in this panel for the power lead.

A vehicle is a high vibration environment, so both the microcontroller and the GPS module must be secured to prevent them from vibrating loose. The best way to do this is to cut two pieces of high-density foam (the type used to package heavy appliances) and glue them to the lid, so that they press down onto these devices when the lid is later fastened into place.

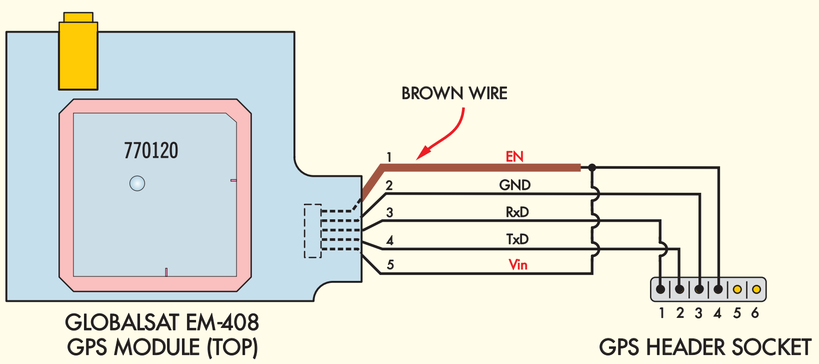


Fig.7: if you use the EM-408 GPS module, cut off one connector from the supplied cable and then solder the cable to a 6-pin header as shown here. This header is then plugged into the GPS header socket on the PCB.

Testing

Before plugging in microcontroller IC1 and the GPS module, you should first test the operation of the power supply. To do this, connect the PCB to a 12V supply and check that there is 3.3V (3.1-3.45V range) between pins 13 (+) and 19 (–) of the IC socket. At the same time, the red fault LED should illuminate.

Next, remove the power and check that the 3.3V rail remains for a few seconds (this indicates that the 4700µF capacitor is doing its job). Wait for this rail to drop to almost 0V, then complete the PCB assembly by inserting the microcontroller and GPS module into their sockets.

Using the tracker

Using the *GPS Tracker* is as simple as applying power, inserting the SD card and checking the three indicator LEDs. The first of these is the power LED; and it only comes on when the microcontroller has completed its self test routine, indicating that both the power supply and the microcontroller itself are OK.

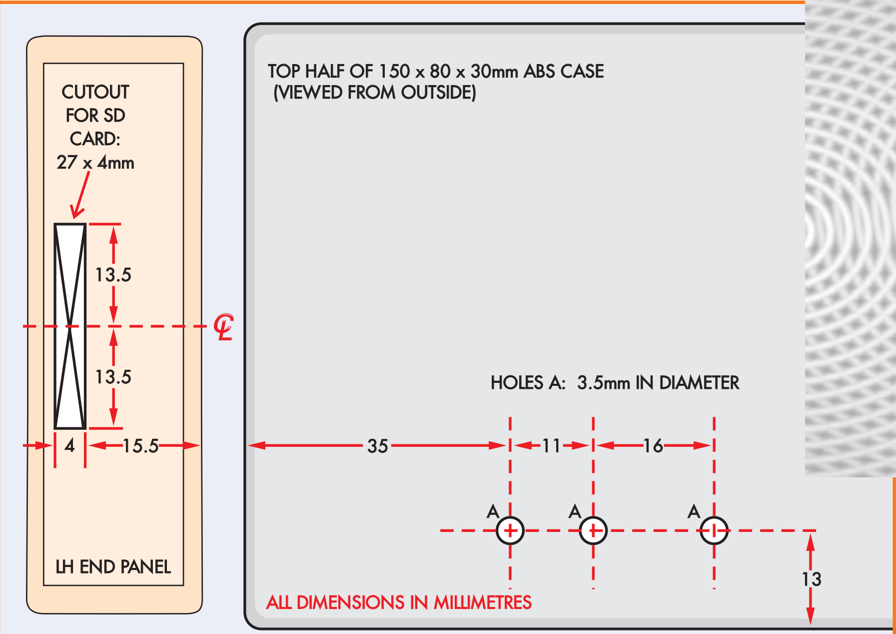


Fig.8: use these two templates to make the SD card slot cut-out in one of the end panels of the case and to drill the holes for the LEDs in the lid.

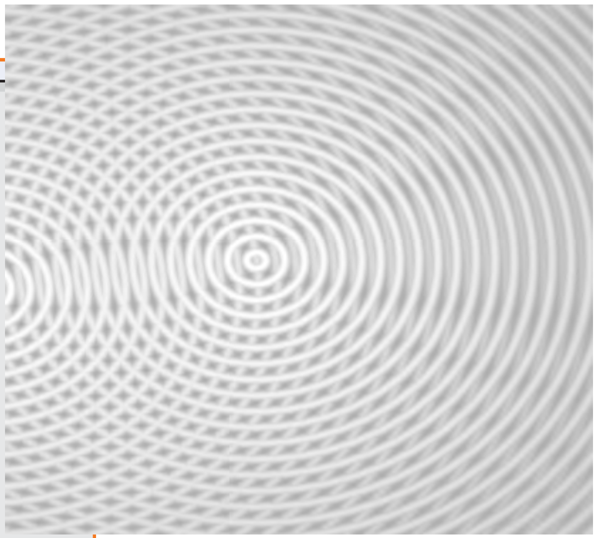


Fig.9 (above): this front-panel artwork can be copied, laminated and attached to the case lid using silicone. It's also available in PDF format on the *EPE* website.

The second is the GPS signal LED. This will be off if the GPS module could not be detected (ie, disconnected); flashing if the module is in communication but has not got a fix on sufficient satellites; and steadily illuminated if it has a fix and a valid latitude and longitude.

Note that you need to be a little patient when you first power it up, as it can take up to 15 minutes for the GPS module to get its first fix. So place the device somewhere where it has a clear view of the sky and give it some time.

The third LED (red) is used to signal a fault. As explained earlier, this LED will come on if a fault is detected, including a faulty or disconnected GPS module, a faulty or unprogrammed microcontroller or a problem with the SD card. Note that a loss of the GPS satellite signal is not counted as a fault because you may be travelling through a tunnel and the *GPS Tracker* will resume recording when you exit and the signal is restored.

If the red fault LED is illuminated, you can deduce the general location of the fault from the other LEDs. For example, if the fault LED is on and both the green LEDs are on, this indicates that the microcontroller and GPS are OK and therefore something must be wrong with the SD card.

Typical problems with the SD card include not being inserted correctly, having the write protect switch in the on position and a corrupted and/or incorrect file system on the card. Any of these will light the fault LED.

When the *GPS Tracker* is running normally, the fault LED will be off and the green power and GPS signal LEDs will be on. Whenever the tracker saves an item of information to the SD card, the power LED will blink momentarily to give an indication that it is active and recording your position.

One point to note is that when you are testing the unit on the bench, you will find that it does not record any data. That's because it will only record trips that cover more than 100 metres. This feature was included to avoid recording trivial vehicle movements, like moving a car from the driveway to the garage.

Installation

Installing the *GPS Tracker* can be as easy as securing it to the top of the dashboard using Velcro (or similar hook and loop material) and using a cable with a cigarette lighter plug for power. For a more permanent installation, it could be placed on the rear parcel shelf, in the glove box or under the dashboard and permanently wired to the vehicle's ignition supply (ie, the 12V supply that's available when the engine is running).

In some locations, such as under the dashboard, it's possible that there will be insufficient signal for the module to acquire or maintain a reliable satellite fix. To assess this, you can carry out a simple test. First, place the *GPS Tracker* on top of your vehicle with a clear view of the sky (no trees or tall buildings) and leave it for half an hour or so to get a solid fix and charge the super-capacitor.

That done, remove the power, swiftly place it in its intended location and reconnect the power. If the signal level is excellent, the GPS module should regain a fix (indicated by a solid green GPS LED) within 10 seconds. If the signal is marginal, it might take up to a minute or more with the LED blinking before a fix is found. Anything between these two is an indication of the signal strength.

If the signal level is inadequate, you could remotely mount the GPS module in a location with a better signal and connect it to the PCB using a 6-core cable up to 2m long. Note that the aerial is on the top of the GPS module and this needs to be aimed straight up at the sky for best reception (ie, the module should be horizontal).

If you are using the EM-408, you can go further and purchase an external antenna with an MMCX connector and plug it into the module. These are available cheaply on eBay and other on-line sources and they will provide a strong signal, even in adverse situations. They are also waterproof and have a magnetic base, so the antenna can be mounted externally on the vehicle with a good view of the sky.

If you are using the two optional inputs (POI and NEW TRACK), then

GPS Tracker Parts List

1 PCB, available from the *EPE PCB Service,* code 05112131, 137mm × 68.5mm
1 ABS box 80 × 150 × 30mm
1 front panel label, 71 × 85mm
1 UP501 or EM-408 GPS module
1 8MHz crystal (X1)
1 15µH 2.1A choke (L1) (Panasonic ELC09D150F or similar)
1 28-pin narrow DIL IC socket
1 tactile pushbutton switch (S1)
1 2-way screw terminal block, 5.08mm pitch (CON1)
1 3-way polarised male header, PCB-mount, 0.1-inch pitch (CON2)
1 Type-B USB socket, PCB mount (CON3)
1 SD memory card connector (CON4)
1 6-pin male header, PCB mount, 0.1-inch pitch (CON5, optional)
1 6-pin male header, PCB mount, 0.1-inch pitch (for GPS module)
1 6-pin header socket, PCB-mount, 0.1-inch pitch (CON6)
4 M3 × 5mm machine screws (or No.4 × 6mm self tappers)
2 momentary pushbutton switches (optional – see text)

Semiconductors
1 PIC32MX250F128B-I/SP microcontroller programmed with 0511213A.hex (IC1) (available from **www.siliconchip.com.au/Shop/9/2477**)
1 Microchip MCP16301T-I/CHY switching regulator (IC2)
2 3mm green LEDs (LED1,LED2)
1 3mm red LED (LED3)
1 IRF540, STP16NE06 or PT3055V MOSFET (Q1, TO-220 package)
1 1N4745 16V 1W Zener diode (ZD1)
1 1N4004 diode (D1)
2 1N5819 Schottky diodes (D2,D4)
1 1N4148 silicon diode (D3)

Capacitors
1 1F 5V super capacitor, PCB mount, 5.08mm lead pitch
1 4700µF 25V electrolytic
4 10µF 25V ceramic, SMD 1206
5 100nF monolithic ceramic
2 22pF ceramic

Resistors (0.25W 1%)

1 27kΩ	3 82Ω
3 10kΩ	1 47Ω
1 8.2kΩ	1 10Ω 1W

Note: a kit of parts for this project is available from Jaycar, Cat. KC5525.

Finding the parts

As usual, a high-quality PCB for the project can be purchased from the *EPE PCB Service* via **www.epemag.com**. A pre-programmed microcontroller (PIC32MX250F128B-I/SP) can be purchased from **www.siliconchip.com.au/Shop/9/2477**, or you can purchase a blank chip direct from Microchip (**www.microchipdirect.com**), element14 (Cat. 2097773/2096412) or RS Components (part 768-0836).

Note, if you purchase a blank microcontroller, you will need a programmer (eg, PICkit 3) to install the firmware. The hex file is available on the *EPE* website.

The voltage regulator (Microchip MCP16301T-I/CHY) can be purchased on-line from Microchip Direct or RS Components (part number 770-9476P). element14 also have the 15µH choke and 10µF SMD capacitors (Cat Nos 8094799 and 1845759 respectively), as do RS Components (part numbers 540-8538 and 758-8093 respectively).

The UP501 GPS module can be purchased from either RS Components (part 716-5283) or Element14 (part 2113837). If you prefer the EM-408 module, it can be purchased from many online parts shops.

Finally, a kit of parts is vailable form Jaycar: **http://www.jaycar.com.au** – catalogue number KC5525.

you will have to add momentary pushbutton switches to short them to ground. The maximum voltage on these inputs is 3.3V, so don't connect them to the vehicle's 12V system **(note: if these switches are mounted remotely from the case, it may be necessary to connect them using shielded cable to prevent glitches).**

Alternatively, the NEW TRACK input can be connected to the vehicle's ignition circuit in order to automatically create a new track each time the ignition is switched off (only necessary if the unit's power supply is not switched with the ignition). This involves connecting a diode between CON2 and the ignition line, with the diode's anode going to CON2. This pulls the NEW TRACK input low each time the ignition is switched off but prevents 12V from being applied to this input (which would damage it).

Fault finding

If you have a problem with your *GPS Tracker*, the first thing to do is check the indicator LEDs. If no LEDs are illuminated it indicates a power supply problem and you should check the input supply for 12V and the regulator output for 3.3V.

If the red fault LED is on but no other LEDs are illuminated, this indicates that the microcontroller has a problem. Most of the time, this will be because it has been inserted the wrong way around. If so, reverse it and pray that it survived. Another possibility is the 10µF capacitor connected to pin 20 of the microcontroller. It must be a low-ESR ceramic device; anything else could prevent the microcontroller from starting up.

If the GPS signal LED does not come on at all, it indicates that the GPS module is not communicating. This could be because it is not plugged in correctly, the super-capacitor is missing, it is configured for the wrong baud rate or it is faulty (unlikely).

If you suspect the module, use the USB connector to connect the *GPS Tracker* to a desktop computer. For Windows, you need to install the USB Serial Port Driver (available on the *EPE* website) but this isn't necessary for Mac and Linux computers, which have built-in drivers. The installation instructions are included with the driver.

Next, use a terminal emulator to open the virtual serial port over USB,

as created by the *GPS Tracker* on your computer. When you do, you should see the NMEA data stream as it is produced by the GPS module. There are many free applications that you can download that can use this data to diagnose your module. If you are a 4WD off-road enthusiast you could connect the tracker to a laptop via USB and use an application like *ExploreOz* which will use the NMEA data stream to pinpoint your position on a map.

You can also use this facility to send commands to the module, but you should avoid changing its baud rate as that parameter will be stored in its internal memory and will be recalled on power up. That could make it impossible to communicate with your module, even after the power has been cycled.

If the NMEA data is missing and everything else is OK (including the supply rail to the module), then the module is probably faulty.

Firmware updates

For firmware updates, you should check the author's website (**http://geoffg.net/tracker.html**). To load a new firmware image, hold down the BOOTLOAD button while applying power to the *GPS Tracker*. The power LED will then flash slowly, indicating that the unit is in bootload mode.

Next, copy the new firmware file (it must be called TRACKER.HEX) to the root directory of an SD card and insert it into the SD card socket. The power LED will then flash rapidly as the image is read from the card and programmed into the microcontroller's flash memory. The whole process only takes about 10 seconds and when it is finished, the *GPS Tracker* will automatically start running the new firmware.

If an error occurs, the power LED will resume its slow flash and the red fault LED will come on. Possible causes include: (1) a missing or incorrectly named hex file, (2) a hex file that is corrupted in some way and (3) a marginal or noisy power supply. After you have identified and corrected the issue, you can run through the bootload process again.

So, there you have it – a versatile gadget that can record a lifetime's worth of travelling. Where are you going to go with it?

This view shows a week-long camping trip as recorded by the *GPS Tracker*. If you are on a long tour, you can use Google Earth to aggregate many individual tracks over many days to provide a 'high-level' view of your progress across the surface of the earth.

Removing the roadblock

TechnoTalk

Mark Nelson

Last month, we looked at how electricity might be generated and distributed in the future. In this issue, Mark Nelson examines what's being done to make electric vehicles more attractive – and entirely affordable.

WHY AREN'T ELECTRIC CARS more desirable? Three obvious reasons spring to mind: they're eye-wateringly expensive, there's a perception that they lack performance and perhaps most important of all, they need to be recharged frequently. 'If we can extend the distance that cars can travel between charge points we will instantly make them more popular,' argues Professor Andrew Forsyth from Manchester University, where its National Graphene Institute is leading a £2 million research project into cheaper electrical energy storage.

But how? According to the professor, a combination of graphene (described below) batteries and supercapacitors could give electric car sales some serious thrust. Today, these green vehicles run on batteries that weigh 200kg – as much as three passengers. By reducing the weight of the batteries, graphene should boost vehicle efficiency and increase the driving range of electric cars to beyond 100km – a limitation that currently discourages their widespread uptake.

Theory must be turned into reality, and Professor Forsyth says a vital task is to discover how graphene batteries cope with the real-life strains of driving. 'Electric cars – like all other vehicles – are not driven smoothly. Dramatic peaks in power demand during acceleration stress the battery and potentially limit its lifespan,' he states. To test whether prototype graphene batteries and supercapacitors are up to the job, the team will expose them to real-world stresses that mimic different driving profiles. 'We can even test the technology for driving in extreme weather conditions,' adds Professor Forsyth. 'Many batteries struggle to perform in cold conditions, but our weather chamber will reveal any weaknesses.'

Miracle material

Graphene can be described as a layer of pure carbon just one-atom thick. For its low weight it is remarkably strong (100 times stronger than steel) and it conducts heat and electricity with great efficiency. Often described as a miracle material, it is also almost perfectly transparent, impermeable to gas, and its properties are, scientists say, easily alterable. This nanomaterial – first isolated at Manchester University in 2004 – has dozens of potential applications, but the one that's crucially important for transport purposes is that graphene could make batteries and supercapacitors light, durable and suitable for high-capacity energy storage from renewable generation sources. In short, it looks to be the perfect candidate for high-capacity energy storage.

Early research has already shown that lithium batteries with graphene in their electrodes have a greater capacity and lifespan than standard designs. Hence, the current research project is exploring different ways to reduce the size and weight of batteries and extend their lifespan by adding graphene as a component material. Manchester academics are working with a number of industrial partners, including Rolls Royce, Sharp and Morgan Advanced Materials. Commercial partnership is crucial for developing the future applications of graphene. The team is currently working with more than 30 companies from around the world on research projects and applications.

Not just batteries or transport

Another focus of the project is graphene-based supercapacitors, which tend to have high power capability and longer cycle life than batteries, but lower energy storage capacity. Despite this, they hold much promise as a complement to batteries as part of an integrated storage solution. In effect, supercapacitors bridge the gap between conventional capacitors and rechargeable batteries. They store more energy per unit of volume or mass than other types of capacitors (up to 10,000 times that of an electrolytic capacitor for instance). On the other hand, while supercapacitors have a *power* density generally 10 to 100-times greater than conventional batteries, their *energy* density is only a tenth or so, resulting in much shorter charge/discharge cycles than batteries. On the plus side, they will tolerate many more charge and discharge cycles than batteries, which is why supercapacitors and batteries work well in combination.

What's more, graphene-assisted energy storage is not limited to transport. It could play a major role in the future of the National Grid as Britain becomes ever more dependent upon renewable energy. 'If we rely on solar and wind power to produce energy, what will happen when clouds block the sun and the wind is just a breeze?' asks Professor Forsyth. 'If we can develop high-capacity electrical storage, operators will be able to store electricity for times of low generation.' His team is installing a grid-scale battery and converter system on Manchester's campus to test large-scale electrical storage. Researchers will use the battery system to develop methods to control the flow of electricity and reconcile differences between power generation and local demand.

Out of the lab and into the factory

Right now, graphene is made only in laboratories, not factories. Earlier this year, however, Samsung Electronics announced a breakthrough synthesis method to speed the commercialisation of graphene. Samsung Advanced Institute of Technology (SAIT), in partnership with Sungkyunkwan University, became the first in the world to develop this new method. 'This is one of the most significant breakthroughs in graphene research in history,' said the laboratory leaders at the SAIT Lab. 'We expect this discovery to accelerate the commercialisation of graphene, which could unlock the next era of consumer electronic technology.'

Until then, engineers around the world had invested heavily in research for making graphene on a commercial scale, but encountered many obstacles due to the challenges associated with it. In the past, researchers found that multi-crystal synthesis – the process of synthesising small graphene particles to produce large sheets of the material – degraded the electrical and mechanical properties of the material, limiting its application range and making it difficult to commercialise. The new method, developed by SAIT and Sungkyunkwan University, synthesises large-area graphene into a single crystal on a semiconductor, maintaining its electric and mechanical properties. The new method repeatedly synthesises single crystal graphene on the same scale used currently for making semiconductor wafers. Time will tell if this process is the one industry has been waiting for, but we can but hope.

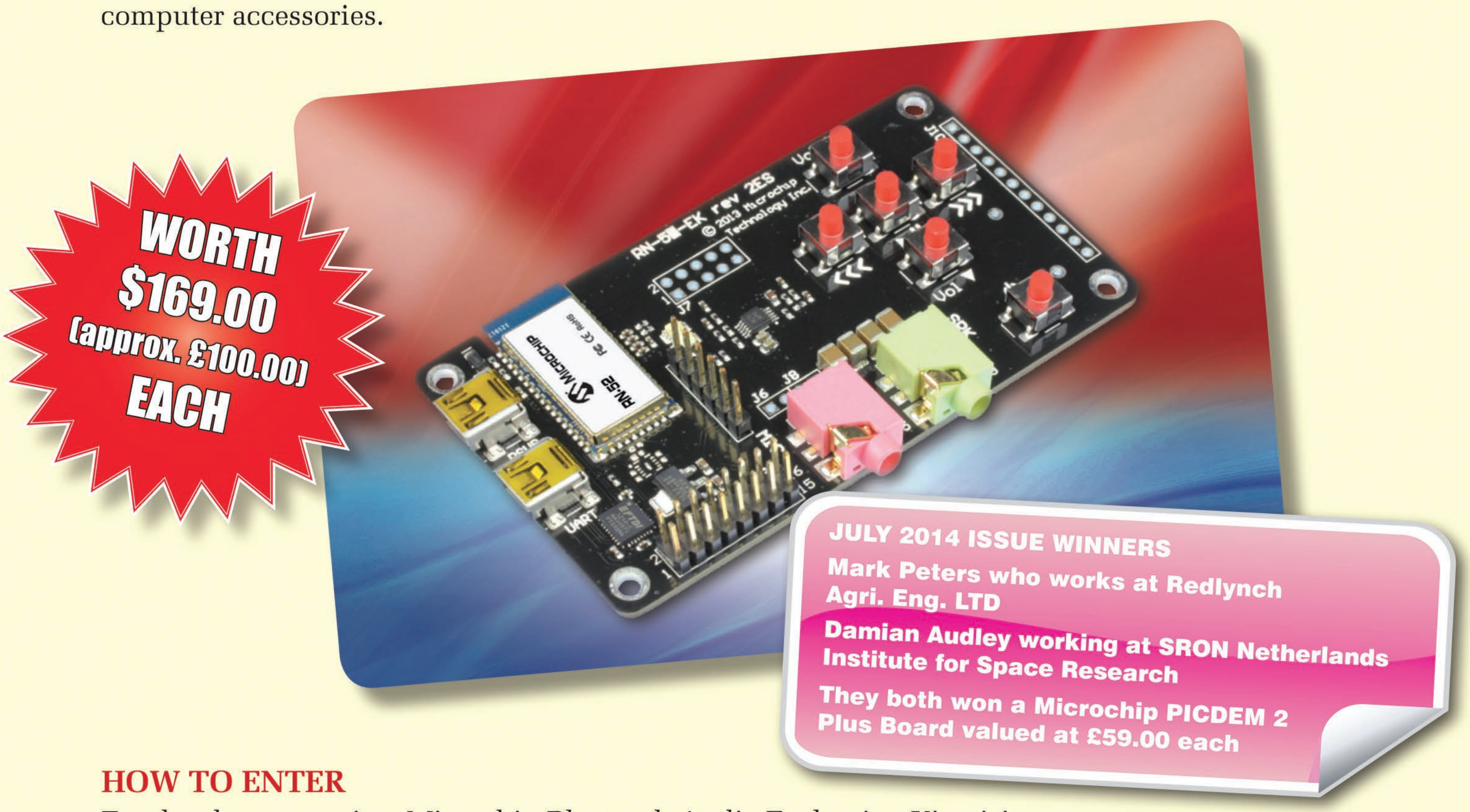
EPE EXCLUSIVE

Win a Microchip Bluetooth Audio Evaluation Kit

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip Bluetooth Audio Evaluation Kit (part No. RN-52-EK). This kit is an evaluation kit for the RN52, a fully certified Bluetooth version 3.0 audio module, and fully compatible with Bluetooth version 2.1 + EDR. It demonstrates the key features of the RN52, allowing designers to quickly and easily evaluate and develop prototypes. With an on-chip Bluetooth stack which integrates all major audio codecs and data profiles, Microchip's RN52 module provides an easy and robust design that works with any microprocessor or microcontroller, to cut time to market for Bluetooth accessories.

The RN52 module also achieves extremely low power consumption and a small, surface-mount form factor, making it easy to integrate high-quality wireless audio and data capabilities in to a broad range of products.

The Bluetooth Audio Evaluation Kit is appropriate for a variety of applications such as: wireless stereo headsets and speakers, automotive hands-free audio, wireless audio docking station for smartphones, intercom push-to-talk audio connection, remote-control for media player, medical devices or computer accessories.



HOW TO ENTER

For the chance to win a Microchip Bluetooth Audio Evaluation Kit, visit **http://www.microchip-comps.com/epe-blueaudio** and enter your details in the online entry form

CLOSING DATE

The closing date for this offer is 31 October 2014

Last month, we introduced our new *Hi-Fi Headphone Amplifier*, which features very low distortion and noise. It can even drive efficient 8Ω speakers. This month, we show you how to build and test it.

By NICHOLAS VINEN

Hi-Fi Stereo Headphone Amplifier – Part 2

THE ASSEMBLY of the *Hi-Fi Stereo Headphone Amplifier* is straightforward, with all the parts mounted on a single PCB, available from the *EPE PCB Service*, coded 01309111 and measuring 198 × 98mm. Apart from the PCB, there is no other wiring.

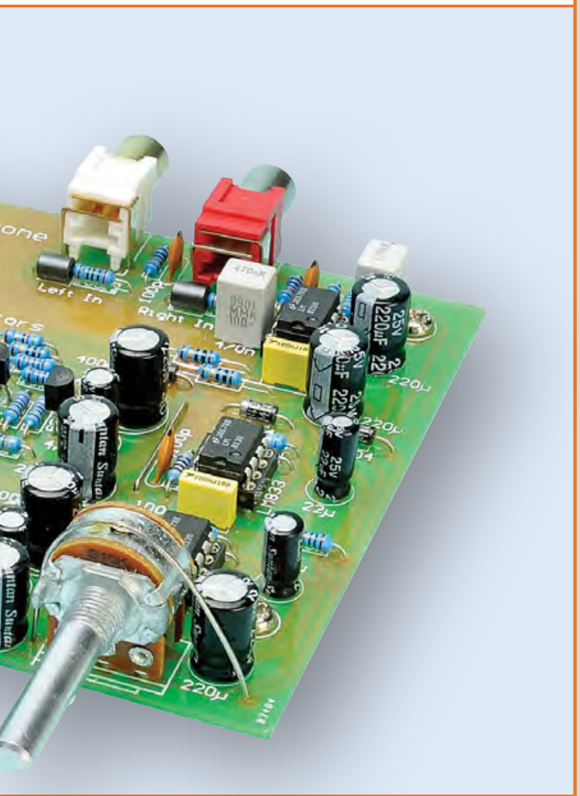
Fig.9 shows the parts layout on the board. Before starting assembly, it's a good idea to test-fit the larger components (eg, the jack socket, heatsinks, RCA sockets and so on) to check that their mounting holes are large enough.

That done, begin by installing the 10 wire links using 0.7mm-diameter tinned copper wire or component offcuts (don't forget the one near CON3). Once those are in, install the resistors, noting that two (both 100Ω just below the RCA sockets) have ferrite beads on their leads. Check each resistor with a DMM set to ohms mode before soldering it into place.

Follow with the 14 1N4004 diodes, taking care to ensure they are all correctly oriented. In each case, the stripe faces to the left or the bottom of the board. The four BAT42/BAT85 small-signal Schottky diodes (D15-D18) near IC1 (upper-left) can then go in. Their orientations vary, so take care.

If you are using sockets for IC1-IC3, install them now with the notches to the right as shown. Alternatively, you can solder the ICs direct to the board with the same orientation.

The MKT and ceramic capacitors are next on the list, followed by the 20 small-signal transistors. There are four different types, so be sure to install the correct type at each location. Use a small pair of needle-nose pliers to crank the transistors leads so that they mate with the board holes and



take care to ensure that each transistor is correctly oriented.

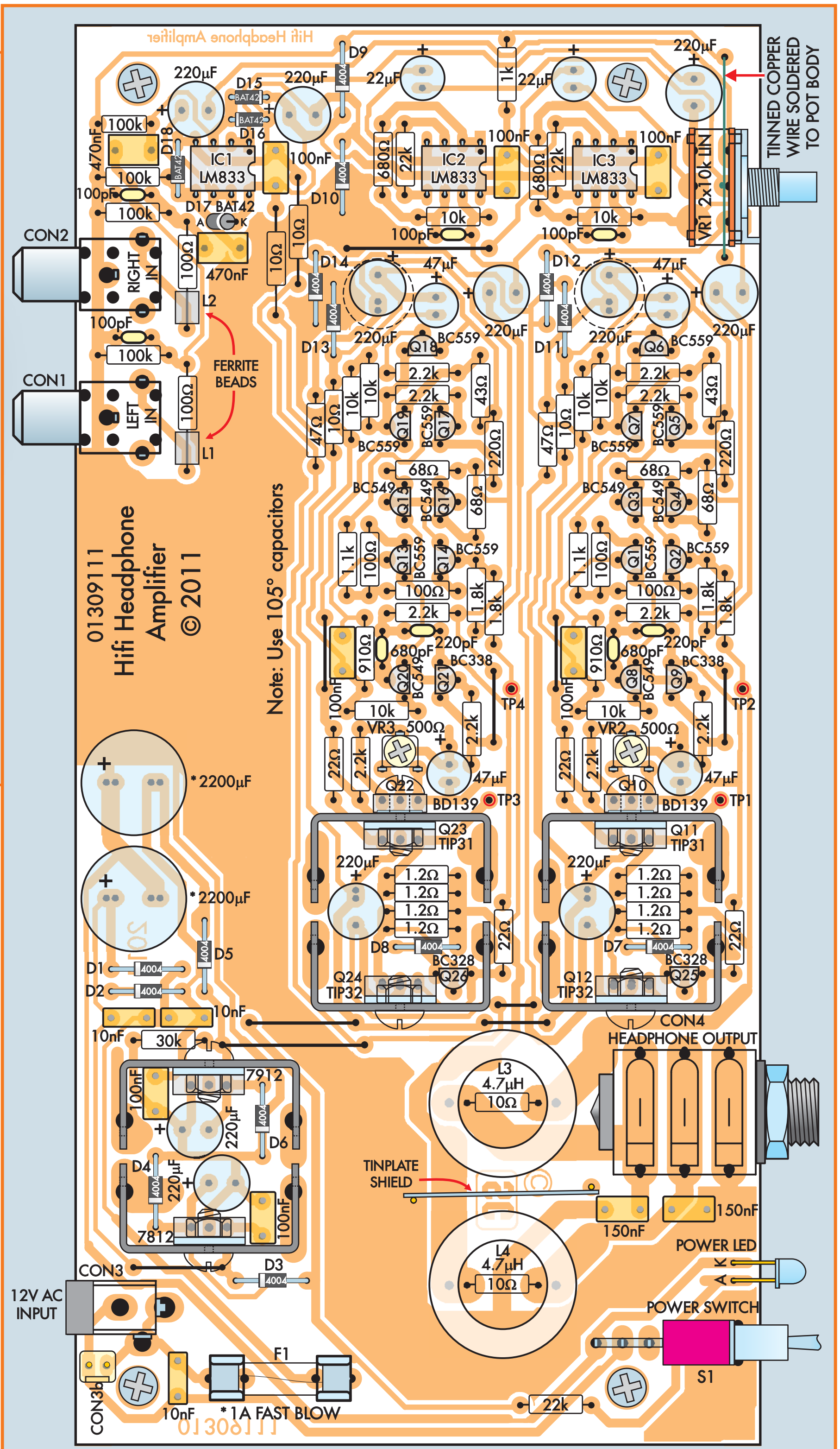
The two 500Ω trimpots and the fuse-holder clips can now go in. Check that the small fuse clip retention tabs are towards the outside before soldering the fuse clips, otherwise you won't be able to fit the fuse later on.

That done, fit PCB pins at test points TP1-TP4 plus another two to support the tinplate shield between inductors L3 and L4. Once they're in, fit the electrolytic capacitors, but leave the two 2200µF filter capacitors out for the time being.

Installing the LED

Before installing the 3mm blue LED, you need to bend its leads down by 90° exactly 4mm from the rear of the lens. Be sure to bend the leads in the right direction though, so that the longer anode lead goes through the hole marked 'A' on the layout diagram.

Once the leads have been bent down, solder the LED in place with the horizontal section of its leads 6.5mm above the PCB surface (a cardboard spacer can be used to set the height). This ensures that it will later line up with its front panel hole and will be in line with the centre shaft of the adjacent switch (S1).



*WHEN DRIVING LOUDSPEAKERS, INCREASE RATING OF F1 TO 2A & REPLACE THESE CAPACITORS WITH 4700µF 25V

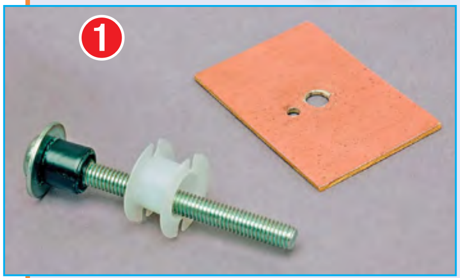
Fig.9: follow this PCB overlay to assemble the *Headphone Amplifier*. Note that the specified case has no ventilation, so we recommend the use of 105° electrolytic capacitors for long-term reliability.

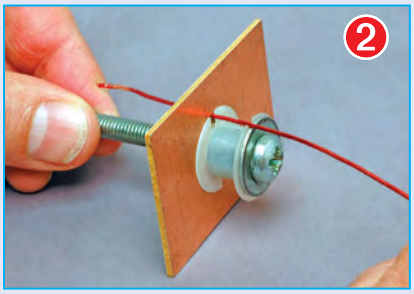
Winding the inductors

The two air-core inductors (L3 and L4) are wound on small plastic bobbins. It is much easier to wind them if you make a winding jig, as shown in the adjacent panel.

To wind the first coil, first secure the bobbin to the jig with one of its slots aligned with the hole in the end cheek. That done, feed about 20mm of a 1m-length of 0.8mm-diameter enamelled copper wire through the

Winding jig for the inductors

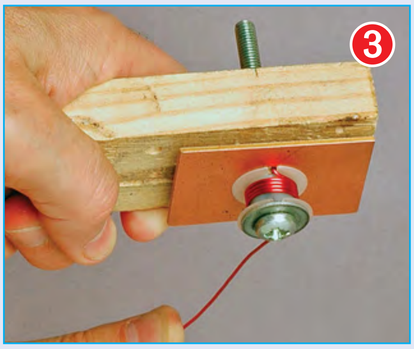




The winding jig consists of an M5 × 70mm bolt, two M5 nuts, an M5 flat washer, a piece of scrap PC board material (40 × 50mm approx.) and a scrap piece of timber (140 × 45 × 20mm approx.) for the handle.

The flat washer goes against the head of the bolt, after which a collar is fitted over the bolt to take the bobbin. This collar should have a width that's slightly less than the width of the bobbin and can be wound on using insulation tape. Wind on sufficient tape so that the bobbin fits snugly over this collar.

Next, drill a 5mm hole through the centre of the scrap PC board material, followed by a 1.5mm exit hole about 8mm away that will align with one of the slots in the bobbin. The bobbin is then slipped over the collar, after which the



PC board 'end cheek' is slipped over the bolt. Align the bobbin so that one of its slots lines up with the exit hole in the end cheek, then install the first nut. The handle is then fitted by drilling a 5mm hole through one end, then slipping it over the bolt and installing the second nut.

hole, then carefully wind on 20.5 turns before bending the end down so that it passes through the opposite slot in the bobbin. Trim the 'finish' end of the wire to 20mm (to match the start end), then secure the winding with a layer of insulation tape and remove the bobbin from the winding jig.

A 10mm-length of 25mm-diameter heatshrink tubing is used to finally secure the winding. Slip it over the outside and gently heat it to shrink it down (ie, be careful to not melt the bobbin).

The second coil is wound in exactly the same manner. Once it's finished, scrape the enamel off the leads on both inductors and tin them before fitting them to the PCB.

Completing the PCB assembly

The PCB can now be completed by fitting the remaining large items, starting with the SPDT power switch. Make sure it sits flat against the PCB and is at right-angles to it before soldering its pins. The power socket can then go in, followed by the RCA sockets (CON1 and CON2).

Use a red RCA socket for CON1 (right) and a white RCA socket for CON2 (left). Be sure to push the sockets all the way down onto the board, so that their plastic locating tabs go into the corresponding holes, before soldering their pins.

The tinplate shield between the two inductors can now be installed. This shield measures 35 × 15mm and can be cut from the lid of a large tin using tin snips. File the edges smooth after cutting, then temporarily position it between the two PC pins and mark their locations.

That done, hold the shield in an alligator clip stand and melt some solder onto either side at the marked locations. It may take 10 seconds or more to heat it enough for the solder to adhere.

Finally, melt some solder onto the tops of the two PC pins before fitting the shield in position and remelting the solder to secure it.

Preparing the potentiometer

The 16mm dual-gang potentiometer (VR1) may need to be modified before installing it on the board. Take a look at the pot – the flat section of the shaft must extend all the way back to the threaded mounting bush. If not, this flat section must be extended.

To do this, lightly clamp the tip of the shaft in a vice with the flat section facing upwards and use a file to extend this section back to the threaded bush. Once that's done, cut the shaft to a length of 7mm and file off any burrs.

It's also necessary to remove a small area of the metal passivation layer on the top of the pot body (use a file), after which the pot can be soldered to the PCB.

The metal body of the pot must be earthed. This is done by first soldering an 80mm-length of tinned copper wire to an adjacent pad immediately below the pot (ie, between it and the adjacent 220µF capacitor). This wire is then looped across the top of the pot, pulled down and soldered to the top-right pad on the PCB and to the pot's body (ie, where you exposed the bare metal earlier).

Mounting the heatsinks

The two regulators and six power transistors are mounted on six large flag heatsinks. These have two posts which pass down through the PCB for support.

Start by loosely fitting the 7812 and 7912 regulators to their heatsinks, as shown in Fig.10(A). Note that, in each case, the regulator's metal tab must be isolated from its heatsink using an insulating bush and silicone washer.

That done, fit the 7812 regulator assembly through the lower set of holes just above CON3 and D3 (see Fig.9). If the heatsink has 'solderable' pins, flip the board over and solder one, then double-check that it is sitting perfectly flush with the board before soldering the other. Since you have to heat up quite a bit of metal, it could take 15 seconds or more before the solder adheres to the post.

Alternatively, if the heatsink doesn't have 'solderable' pins, use pliers to bend the tabs outwards far enough so that it is secured to the board.

Having secured the heatsink, check that the insulating washer is properly

The PCB assembly is a neat fit inside the recommended case. Note how the body of the volume control pot (top, left) is earthed using a length of tinned copper wire. This wire is looped across the top of the pot's body and is terminated in solder pads on either side (see Fig.9).

aligned with the regulator and tighten the mounting screw. The regulator's leads can then be soldered. Repeat this procedure for the 7912 regulator.

The two TIP32 power transistors (Q12 and Q24) are mounted in identical fashion to the regulators. By contrast, the heatsinks for the two TIP31 power transistors (Q11 and Q23) have the BD139 V_{BE} multiplier transistors mounted on the other side. Fig.10(B) shows the mounting arrangement. Be sure to insulate all the transistors from the heatsinks using silicone washers and insulating bushes as necessary.

You can now fit the 6.35mm jack socket. The type we used does not sit right down on the board due to the shape of its pins, but rather sits above the board by about 4mm. If your jack socket does not have 'necked' pins, you will either need to extend them or its front panel hole will have to be lowered by 4mm when you drill it later.

Finally, fit the two 2200µF capacitors. As mentioned in Part 1, if you use 4700µF 25V capacitors (ie, for more output power), they must be no taller than 30mm and no more than 16mm in diameter, otherwise the assembly will not fit into the specified case.

Test and adjustment

The assembled board can now be tested. First, turn both trimpots and the volume control potentiometer fully anti-clockwise, then clip a multimeter set to its highest AC amps mode across the fuseholder (without the fuse in place). The easiest method is to use alligator clip leads.

Next, connect the 12VAC plugpack and apply power. You should get a reading of 120mA ±20mA (no op amps installed) or 160mA ±20mA (op amps installed). If the current does not fall inside this range after about a second, switch off the plugpack at the wall and check the board for faults such as solder bridges between pads and tracks.

Assuming it's OK, switch off, install the op amps if they aren't already on the board and check the current consumption again (ie, it should be 160mA ±20mA).

Now turn the power off, install the fuse and connect a multimeter set to volts/millivolts mode between TP1 and TP2. That done, switch on and check the reading – it should be very close to 0mV.

Now slowly adjust VR2 clockwise. At first, nothing will happen, but eventually the reading should start to rise. Adjust it for a reading of 28.5mV. This sets the quiescent current in the left channel to 47.5mA. Note that this reading may slowly rise as the transistors warm up, so leave it on for a few minutes and then re-adjust it.

Once that's done, switch off and connect the multimeter between TP3 and TP4. VR3 can now be adjusted

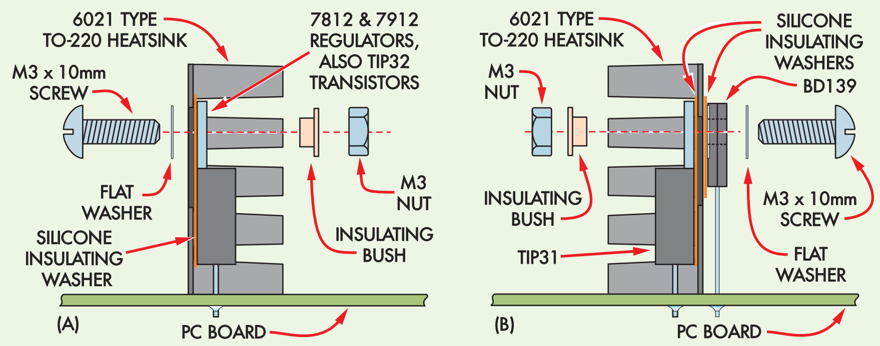


Fig.10: follow this diagram to install the regulators and output transistors on their heatsinks. Make sure that the metal tabs of all devices are isolated from the heatsinks using insulating washers and bushes as required. Note that the heatsinks should be either soldered or clamped to the PCB before soldering the device leads, to avoid stress fractures.

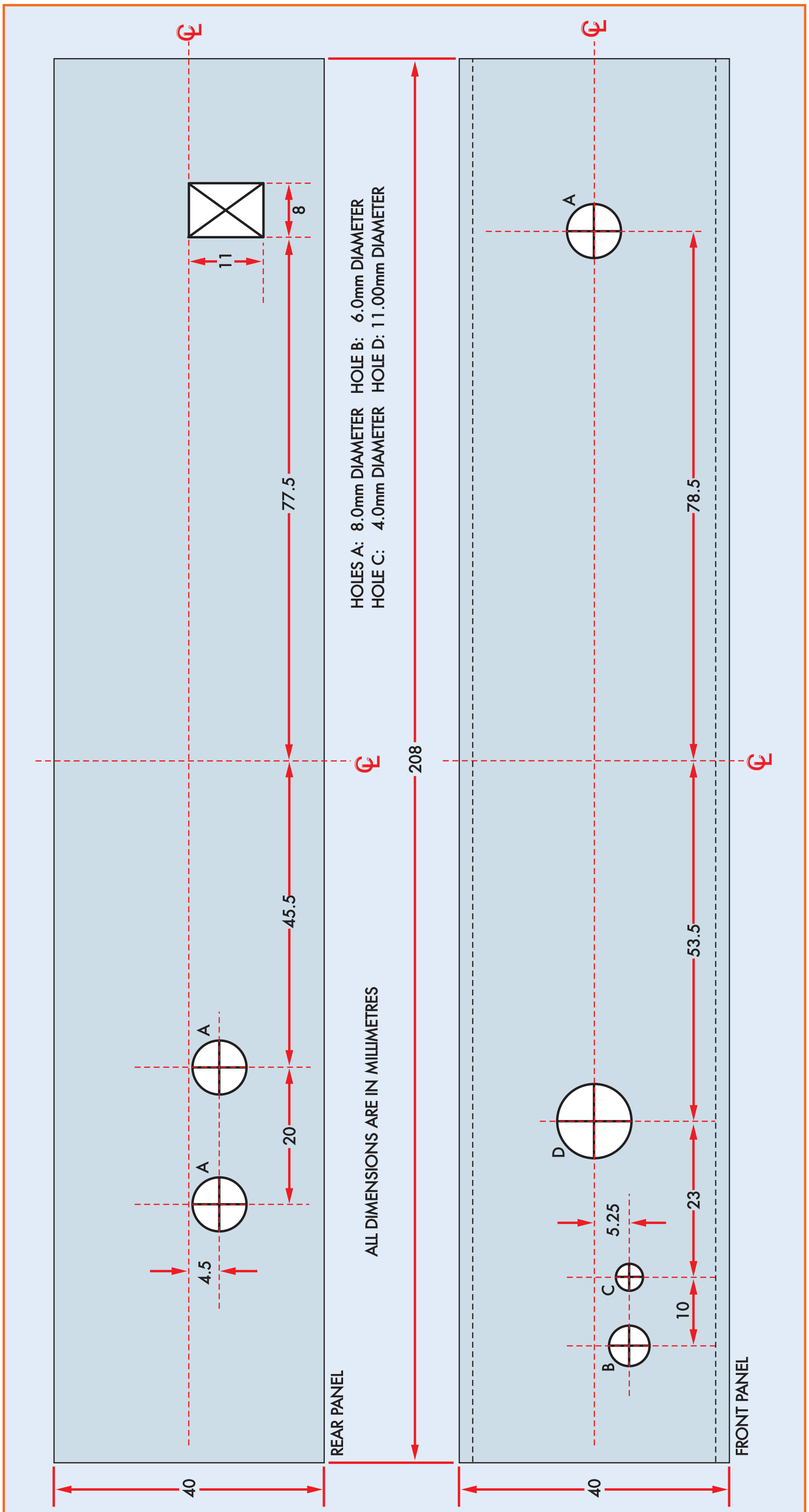


Fig.11: the drilling templates for the front and rear panels. Start each hole with a small pilot drill and then enlarge it using larger drills and a tapered reamer as necessary. The rectangular cut-out is made by drilling and reaming a 6mm hole in the centre and then shaping it using a flat needle file. Be sure to correctly position the templates before drilling the holes.

for a reading of 28.5mV, to set the quiescent current in the right channel.

The final test is to connect a signal source and headphones and slowly turn the volume up. If you hear clear, undistorted sound from both channels then the board is working properly.

Provided the quiescent current is set correctly for both channels, the idle current will be about 340mA (AC RMS), giving a power consumption of about 4W. With headphones, this does not usually increase but it may be higher when driving loudspeakers, depending on the volume level and speaker efficiency.

Drilling the case

A half-size 1-unit steel case is used to house the PCB assembly. Other cases are also suitable provided the PCB fits, although you will probably have to chassis-mount the RCA input sockets and power connector. If chassis-mounting the RCA connectors, it will be necessary to use shielded cable to connect them to the PCB.

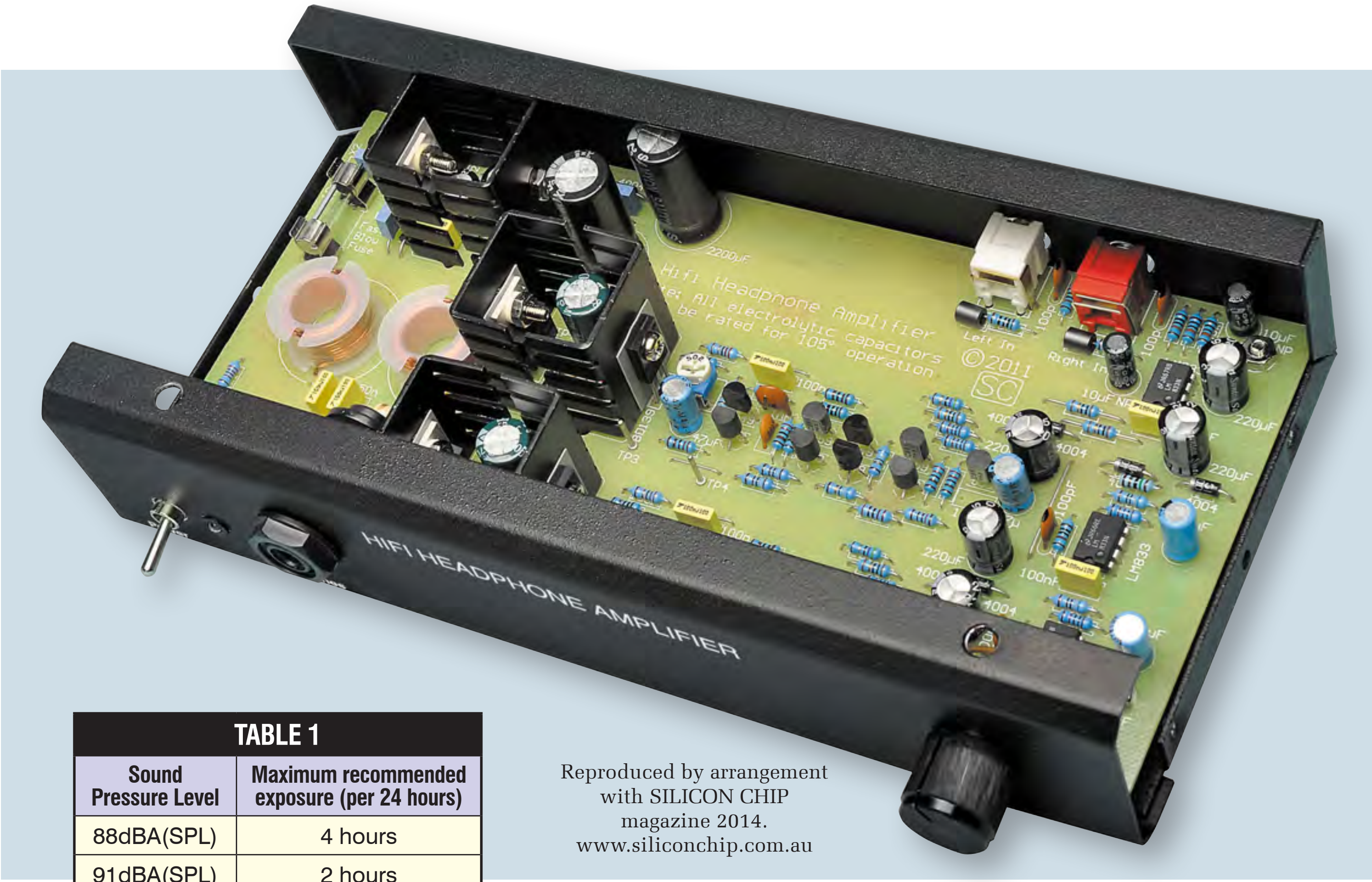
The drilling templates for the case are shown in Fig.11. Disassemble the case entirely first, by removing all the screws. It separates into three pieces: the aluminium base (and rear panel), the front panel and the steel lid. Remove the feet as well and place them and the screws into the provided snap-lock plastic bag for safe-keeping.

Next, download and print out the drilling templates and attach them to the front and rear panels. Use a punch to mark the centre of each hole. Alternatively, you can start the holes with a small bit (say 1mm) and a hand-drill. Either way, drill pilot holes (eg, 1.5mm) in each location before enlarging them to size using larger drills and a tapered reamer.

The hole which must be the most accurately placed is that for the power switch. The LED leads can be bent to compensate for any inaccuracy in its mounting hole position and those for the output socket and volume control can just be made slightly oversize. Note that the hole for the power LED is drilled to 4mm to suit a plastic LED clip.

The rectangular cut-out for the power socket is made by first drilling and reaming a 6mm hole in the centre before carefully enlarging it to a rectangular shape with a flat needle file.

Once the drilling has been completed, download the front and rear



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Another view inside the completed unit. Make sure that the screws used to secure the lid clear the underside of the PCB – see text. Note that the PCB shown here is a prototype and differs slightly from the final version shown in Fig.9.

TABLE 1

Sound Pressure Level	Maximum recommended exposure (per 24 hours)
88dBA(SPL)	4 hours
91dBA(SPL)	2 hours
94dBA(SPL)	1 hour
97dBA(SPL)	30 minutes
100dBA(SPL)	15 minutes
103dBA(SPL)	7 minutes
106dBA(SPL)	3 minutes
109dBA(SPL)	1 minute
112dBA(SPL)	30 seconds
115dBA(SPL)	15 seconds

panel labels (in PDF format) from the *EPE* website (**www.epemag.com**) and print them out. These labels can then be trimmed and laminated before affixing them to the panels using double-sided adhesive tape. The holes are cut out using a sharp hobby knife.

Mounting the board

The PCB assembly is mounted on the same machine screws that secure the rubber feet to the case. Remove the supplied short machine screws from the feet and insert M3 × 15mm screws instead, then re-attach them to the base. Once they're all in place, slip three M3 flat washers over each screw thread, then fit a nylon nut/washer combination over the top, with the larger 'washer' section at the top (note: if you can't get these, use separate nylon nuts and washers instead, with the washers on top). Next, undo the two rear screws until only a tiny bit of thread is sticking out above the nylon washers (say 1mm), then introduce the board by pushing the RCA sockets and DC input connector through their respective holes. It's then just a matter of dropping the front of the board down onto the screw threads, after which you can re-tighten the rear mounting screws.

The lid is held in place by two screws on each side and these should just clear the underside of the PCB. Temporarily fit these screws (ie, without the lid) to check this. If any of the screws do foul the PCB you will need to remove it and add more M3 flat washers under the nylon nuts.

Once it's correct, fit M3 nuts to all four screws to secure the PCB in place, then remove the nuts and washers from the jack socket and volume control pot. The front panel can then be attached by slipping it into place and installing the two screws at the bottom. Once it's secured, push the plastic LED clip into place and push the LED into the clip from the back.

The assembly can now be completed by reinstalling the washers and nuts for the jack socket and volume control, attaching the knob and fitting the lid.

Using it

Finally, here are a couple of tips for using the *Headphone Amplifier*.

Always turn the volume knob right down before donning the headphones and then turn it up to a comfortable level. If you don't do that, you risk hearing damage. This particularly applies if somebody has left the volume control turned fully up or if the signal source is much louder than it was the last time you used the headphone amplifier.

Similarly, do not listen at high volume levels for long periods. This is especially critical with a headphone amplifier – it's easy to expose yourself to damaging sound pressure levels without too much apparent discomfort (and without anyone else noticing).

Table 1 shows the recommended maximum exposure periods for various sound pressure levels (SPLs) ranging from 88-115dBA. **In short, don't make a habit of listening to loud music via headphones!**

SiDRADIO: an integrated SDR using a DVB-T dongle

. . . incorporating a tuned RF preselector/amplifier, an up-converter and coverage from 'DC to daylight'

Last month, we introduced our SiDRADIO communications receiver and described the circuit and PCB assembly. This month, we show you how to make and fit the various metal shields and complete the construction by installing it all in a plastic instrument case.

Part 2: By JIM ROWE

AS STATED last month, the PCB assembly and its companion DVB-T dongle are housed together in a low-profile ABS instrument case. Since the case itself provides virtually no EMI shielding (apart from new front and rear panels which are made from double-sided PCB laminate), the fairly high sensitivity of the front-end circuitry means that extra shielding must be added to achieve an acceptable level of performance.

In fact, three separate shields are necessary: (1) a small vertical shield in the front centre of the PCB (see Fig.6 in Part 1 and the internal photos); (2) a lower horizontal shield; and (3) an upper horizontal shield.

Fig.10 shows the details for the small vertical shield. It's made from 0.8mm-thick sheet aluminium or tinplate which is first cut to size and then bent up in a small bench vice.

A 3.5mm hole near the front of the mounting flange allows this end to be secured under the PCB's front-centre mounting screw, while a second hole (at the rear) lines up with a matching hole near the centre of the PCB.

Once this shield has been made, secure it to the PCB via its rear mounting hole using an M3 x 9mm machine screw, lockwasher and nut (feed the screw up from underneath the PCB). This not only secures the shield in place, but also ensures that it is connected to the PCB's earth copper.

Fig.11 shows the dimensions and cutting details of the lower horizontal shield – but note that this diagram is drawn half size (50%) for space reasons. This shield is cut from 0.25mm copper foil or tinplate, and requires a small semicircular cut-out near its front centre, to provide clearance for the tuning knob (note: PCB laminate material is too thick for the bottom shield).

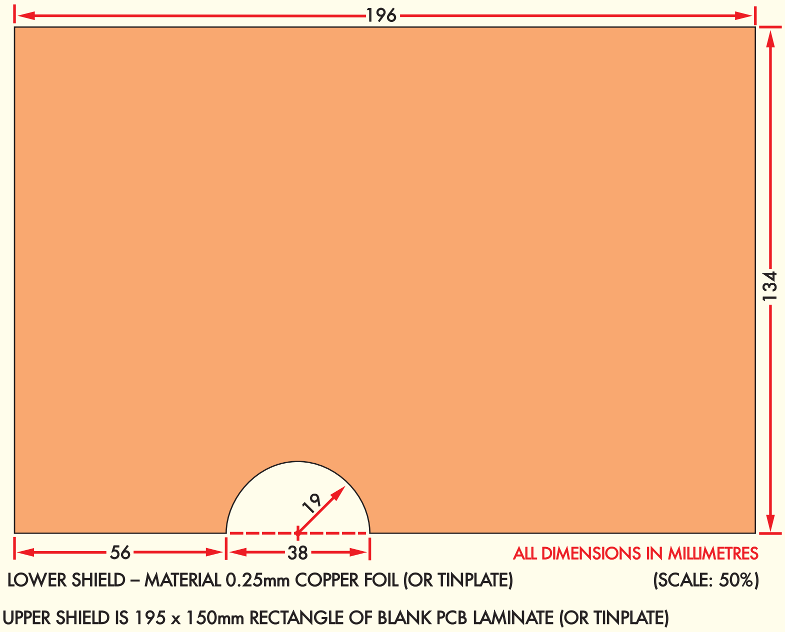


Fig.11: the lower horizontal shield is cut from 0.25mm-thick copper foil or tinplate and requires a semi-circular cutout as shown so that it clears the tuning knob. Note: diagram drawn to 50% scale.

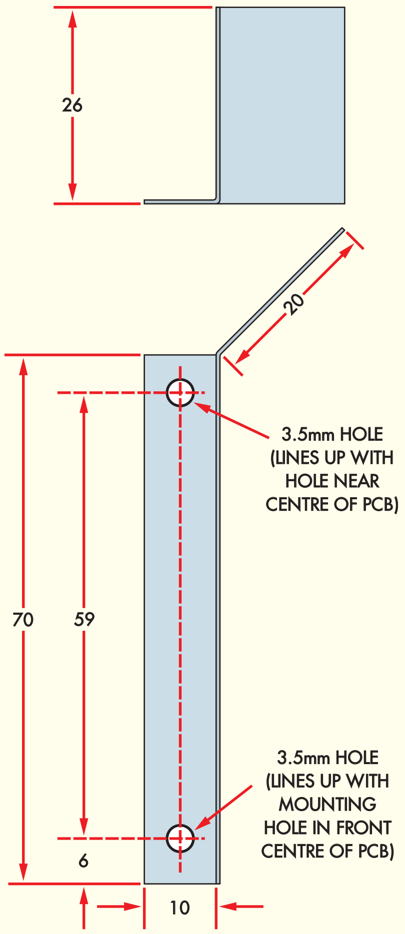


Fig.10 (left): here's how to bend and drill the vertical shield that's mounted on the main PCB. It's bent up from 0.8mm-thick sheet aluminium or tinplate.

When it has been cut to shape, this shield can be fitted inside the bottom of the case and secured using double-sided foam tape. Note that, depending on the case supplied, it may be necessary to cut away a number of central pillars using side-cutters or a chisel, so that they don't foul the shield.

Note also that you must leave a small area of exposed copper (or tinplate) near the lower lefthand (front) corner so that you can solder a short length of hookup wire to it. The other end of this wire is later connected to the GND terminal pin (TPG2) in that corner of the main PCB.

The upper horizontal shield is simply a rectangle measuring 195 ×150mm and is cut from either blank PCB laminate or tinplate. This is secured inside the top of the case using double-sided foam tape. As with the bottom shield, you need to solder a short length of hook-up wire to it, this time at the left rear (ie, roughly above CON3). This wire is subsequently used to connect the top shield to the PCB earth copper via TPG3.

Front and rear panels

Although the case is supplied with ABS front and rear panels, they cannot be used here as they don't provide any shielding. Instead, these panels are replaced with custom panels made from doubled-sided PCB material. These PCB front and rear panels (code 06109132 and 06109133) are available from the *EPE PCB Service* (see our website) and are supplied pre-drilled with red solder masking and silk-screened lettering for a professional finish (see photos).

Both panels also have a solder pad at one end (on the inside) so that they can be connected via short lengths of hook-up wire to the adjacent earth (TPG) pin on the main PCB. This, together with the added shields, ensures adequate RF shielding for the sensitive front-end circuitry.

Preparing the case

The upper half of the case needs no preparation at all, apart from fitting the upper shield as described earlier. However, as stated above, it may be necessary to cut away some central pillars on the lower half of the case.

In addition, it's necessary to remove a 30.5mm-long section of the ribs on either side of the front-panel mounting slot, to provide clearance for the tuning knob. This can done using a hand-held rotary tool after first marking the section to be removed, using the front panel as a guide.

Just remove enough material from the ribs to bring them down to the same level as the inside bottom of the case.

Adjusting the rotary switch

Before fitting rotary switch S2 to the front panel, you first need to trim its shaft to about 9mm. It then needs to be converted from a 6-position switch to a 5-position switch.

That's done by first rotating the switch fully anticlockwise and removing the mounting nut and lock-washer. The indexing plate is then lifted up and replaced with its pin going into the hole between the '5' and '6' digits moulded into the switch body.

The rear panel carries the two antenna sockets and has a cutout to provide access to the USB socket. Note the two earth leads running from TPG2 to the rear of the front panel and to the bottom horizontal shield. Note also that the mounting screw used to secure the central shield near transformer T1 is fed up from the underside of the PCB.

Check that the switch now has five positions, then fit a flat washer over the indexing plate, followed by the lock-washer. The switch can then be fitted to the front panel and secured with its mounting nut.

Once the switch is in position, cut 12 × 40mm lengths of light-duty hook-up wire (eg, from a short length of multi-colour ribbon cable). Remove about 5mm of insulation from the ends of each wire, lightly tin the bared ends and solder two of these wires to the centre (rotor) lugs on the rear of the switch. The other 10 wires should then be soldered to outer lugs 1-5 and 7-11 – see Fig.6 in Part 1.

Note that these digits are moulded into the rear of the switch and you must solder each one to its corresponding number on the PCB (the switch diagram in Fig.6 is representative only). The rotor connection lugs are identified as 'A' and 'C' (the latter going to the 'rotor B' pad on the PCB).

Final assembly

Now for the final assembly. The first step here is to mount the PAL/Belling Lee socket (CON4) on the rear panel. This must be fitted with its earth lug-washer, lock-washer and nut on the inside and oriented so that the earth lug is at the same level as the rear centre pin. The earth lug must also be to the right of the centre pin, as viewed from inside the case (see Fig.6 in Part 1).

Next, remove the mounting nut from HF input socket CON3, leaving the lock-washer in place, then fit the rear panel over CON3. That done, refit the mounting nut, but don't tighten it up fully at this stage. Adjust the panel so that CON4's centre pin rests on its rectangular connection pad on the top of the PCB, just to the rear of RLY1.

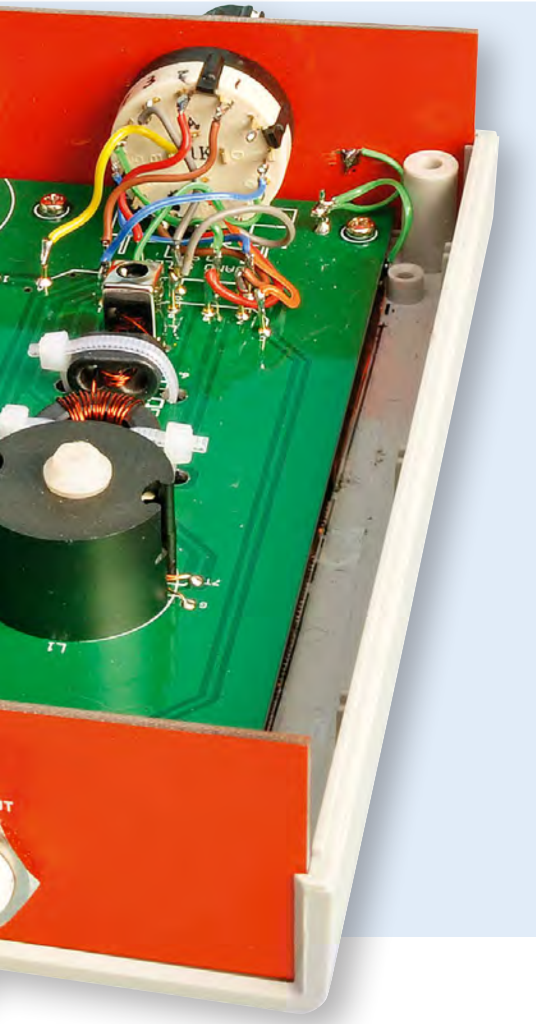
The front panel can now be fitted to the main PCB assembly. First, remove VR1's mounting nut but leave the lock-washer in place, then attach the panel with VR1's shaft, LED1 and toggle switch S1 all passing through their matching holes. VC1's tuning knob should also be protruding through its clearance slot, while the body of rotary switch S2 should be just resting on the top of the PCB.

Once it's in place and lined up correctly, fit a flat washer to VR1's threaded ferrule and then refit its mounting nut to hold it all together. The completed assembly can then be lowered into the case, with the front and rear panels slipping down into the matching slots on either side.

During this procedure, make sure that the end of the earthing wire for the lower shield is accessible, down at the front lefthand corner.

Once it's in place, check that the main board is seated properly, then fit the 10 4-gauge × 6mm self-tapping screws to secure the PCB inside the case. These screws all mate with the small mounting pillars that are moulded into the bottom of the case. Note that the screw in the front centre position on the PCB also passes through the front hole of the vertical shield plate.

The next step is to solder all the wires from the rear of rotary switch S2 to their correct terminal pins on the PCB. It's just a matter of matching the



pin numbers and letters on the switch to those on the PCB.

Earthing wires

Next, solder the end of a short piece of hook-up wire to the earth pad on the back of the front panel (near S2), then solder the other end of this wire to the adjacent PCB earth pin (TPG2). The wire from the lower shield should then also be connected to TPG2. This connects both the front panel and lower shield to the main PCB's earth copper.

Similarly, connect TPG3 to the earth pad just to the right of CON3 on the rear panel. That done, connect CON4's earth lug to its PCB pad using a short length of tinned copper wire.

The assembly can now be completed by fitting the control knobs to band switch S2 and to RF gain pot (VR1) and then plugging in the DVB-T dongle.

Fitting the DVB-T dongle

As shown in Fig.6 in Part 1, the DVB-T dongle fits into the cut-out at the righthand end of the PCB, with its USB plug mating with CON2 at the rear. If necessary, it can be further secured using hook and loop material (eg, Velcro) attached to the underside of the dongle and to the bottom of the case.

The DVB-T dongle's RF input is connected to the PCB via a 100-120mm length of 75Ω coaxial cable fitted with a PAL/Belling Lee plug (or whatever plug is needed for your dongle) at one end. The other end is simply stripped and the centre conductor and screening braid soldered to the appropriate PCB pins.

By the way, if your dongle came with one of those cheap baby whip antennas, you can make use of its antenna cable to avoid having to make up a new one. Simply cut the cable about 120mm from the dongle plug end and connect this end to the terminal pins on the PCB.

In fact, this is the best way to go if your dongle uses a small MCX connector for its RF input.

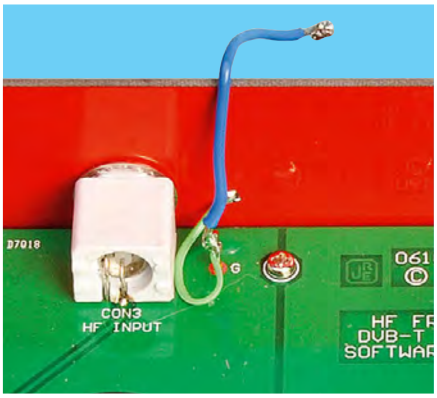
Initial checkout

Your completed *SiDRADIO* is now ready for initial testing. All that's necessary to do this is to move toggle switch S1 to its upper position and then connect CON1 to your PC via a standard USB cable (ie, with a USB type A plug at the PC end and a USB type B plug at the *SiDRADIO* end).

Provided you have already installed the RTL-SDR driver and an SDR application like SDR# , Windows should recognise the dongle as soon as the USB cable is plugged in. Assuming that's the case, connect a suitable VHF/UHF antenna to CON4 of the *SiDRADIO* and fire up SDR#. You should now be able to see any VHF-UHF signals that are being picked up by the dongle in the usual way, ie, just as if the dongle were plugged directly into the PC's USB port.

If all goes well, click on SDR#'s STOP button and switch on the *SiDRADIO* using power switch S1. Check that LED1 turns on, then check the output from the DC-DC converter (IC2) by measuring the voltage between 'TP 12V' and 'TPG4' on the PCB (these two test points are just to the right of the vertical shield plate). You should get a reading of close to 12.5V when gain control VR1 is turned fully anti-clockwise, dropping to around 12.0V when VR1 is turned fully clockwise.

You should also check the voltages at the input and output of REG1, located



Terminal pin TPG3 (to the right of CON3) is connected to the earth pad on the rear panel using insulated hook-up wire, while a second lead (shown here as the blue wire floating at one end) must be connected from TPG3 to the top horizontal shield.

just to the rear of T2. The voltage on its input pin (on the right) should be very close to 5.0V, while the output pin (on the left) should be very close to 3.3V.

If these voltages all measure OK, the *SiDRADIO's* front-end LF-HF circuitry is probably working correctly. If so, connect a suitable LF-HF antenna to CON3, use rotary switch S2 to select a suitable band (say Band 3, 1-3.4MHz), and set RF gain pot VR1 to mid-way. That done, click on the small box just to the left of the 'Shift' label in SDR# on your PC and set it to make allowance for the 125MHz up-conversion. Finally, click on SDR#'s 'Play' button again to resume operation.

You should now see a spectrum display of LF-HF signals and if you set SDR# to scan in that part of the spectrum centred on about 1.0MHz, you should see a number of signal peaks corresponding to various AM radio stations. Then if you select one of these peaks, you should be able to tune it for maximum signal by nudging the *SiDRADIO's* tuning knob one way or the other.

Note that the tuning is fairly broad and not at all critical.

Note also that if the signal you wish to tune is near the top of the band, you may need to adjust the small trimmer capacitors on VC1 to their minimum settings (ie, fully unmeshed). They're easily accessed through small holes in the top of VC1 and can be adjusted using a small screwdriver or alignment tool.

You should now find that advancing RF gain control VR1 produces an obvious effect on SDR#'s display. In fact, if you turn VR1 up to 'full bore', this may well cause the signal peaks to rise above the overload level. In most situations, you'll rarely need to turn the RF gain up that far.

Finishing up

There are no further adjustments and the operation should now be quite intuitive. **All that remains is to solder the end of the wire from the upper shield plate copper to terminal pin TPG3** on the main PCB (near CON3), after which you can fit the top half of the case into position and secure it using the four supplied screws.

You should also fit four adhesive rubber feet to the bottom of the case, so that it won't scratch any surface it's placed on.

You're now free to explore the LF, MF and HF bands in the same way that you've been exploring the VHF and UHF bands. And of course, you can return to exploring the VHF and UHF bands at any time simply by switching the *SiDRADIO* off and clicking again on the box just to the left of SDR#'s 'Shift' label to de-activate the 125MHz frequency offset.

Next month – software

Now that we have the finished hardware it is time to look at the software that runs the system. All will be revealed next month!

You may need to install .NET Framwork 2.0

A reader discovered that the SDR software combination (Zadig + RTL-SDR + SDR#), would not run on a PC with Windows XP (SP2) even tough it ran on another Windows XP/SP2 machine.

The solution was to install Microsoft .NET Framework 2.0 and reboot.

Newer operating systems may come with this preinstalled. If you do need to install Microsoft .NET Framework 2.0, it can be downloaded from the Internet. Note that this note also applies to the SiDRADIO.

50 Golden Years Of Practical Electronics PART 1

by Alan Winstanley

A brave new world

The November 2014 issue of *Everyday Practical Electronics* marks a very special milestone in the evolution of our title: we are proud to celebrate the 50th anniversary of Britain's *Practical Electronics* magazine, a title launched half a century ago in 1964 and which has evolved into today's modern *EPE Magazine*.

Practical Electronics was a new addition to the emerging family of 'Practical' home and hobby magazines published by George Newnes in London, joining the radio journal *Practical Wireless*, which first appeared in 1932 and became the largest selling publication of its kind, peaking at 120,000 printed copies a month. *Practical Electronics* would be designed to offer a broader appeal in the world of hobby electronics and was committed, in the words of its editor Fred Bennett, 'to explore, unreservedly, all its practical possibilities'.

The team at *Practical Wireless* had suggested the new magazine and in 1962 Fred Bennett officially went to work for *'PW'* – or so he thought. The truth dawned as Fred was eventually tasked with preparing a new title, to be called (probably at his suggestion) *Practical Electronics*, and his close personal involvement with the development of *Practical Electronics* was in reality pre-ordained by Newnes. The gestation period of *Practical Electronics* was surprisingly long, explained Fred in 1989, as more than a year passed while Newnes chewed over some mock-ups for the proposed magazine.

First issue

Finally, after receiving the go-ahead at the end of 1963, the first issue of *Practical Electronics* was eventually published the following year in October 1964, less than 20 years after the end of the war when the need for thrift,

make-do and resourcefulness rubbed shoulders with highly skilled engineers, ex-military types, keen amateurs and talented professionals alike – all potential readers (and contributors) for the new magazine.

Such was the intense interest in the subject that about 115,000 copies of the first edition were sold. As Fred explained, the November 1964 Vol. 1 Issue 1 of *Practical Electronics* was launched in a post-war era that heralded the dawn of a 'white-hot technological revolution,' as Britain's then Prime Minster Harold Wilson put it. With the Space Race beckoning, there was no doubt that electronics would have a pivotal role to play in the technological revolution that lay just over the horizon. Many exciting discoveries and advances were promised, with *Practical Electronics* playing a key role in enthralling, enthusing and educating its dedicated new readership.

The very first issue of *Practical Electronics* arrived in 1964. It was packed with features and mail order advertisements

Limitless talent

Editor Fred Bennett was worried that there would be insufficient material contributed each month, but at no time did this prove to be the case and he soon realised that he had 'begun to tap an inexhaustible source of talent'. He said that 'scores of amateurs and professionals were swift to offer their projects,' and he would often have to make difficult choices about what to publish, and what to reject.

Aided by the advent of the germanium diode and transistor, a procession of constructional projects was eagerly devoured by readers hungry to challenge their skills in building their own electronic circuits. Issue 1 offered a taste of things to come, with a 5W integrated amplifier (all-transistor), a Geiger-Muller ratemeter, a VHF receiver and a Morse practice oscillator. A feature on 'Semiconductors for Automobiles' highlighted offerings by Lucas in electronic ignition systems for (positive earth) cars.

PCBs and Veroboard from day one

Printed circuit board foils were offered right from the start, with cellulose paint recommended as etch resist and a fearsome cocktail of ferric chloride and hydrochloric acid suggested for etching boards at home. Mercifully, stripboard assembly quickly followed in *Practical Electronics*, with December 1964's issue already having a pull-out blueprint featuring two projects using the new 0.15-inch pitch 'Veroboard System'. This SRBP circuit panel of milled copper strips and a precision matrix of punched holes was a truly brilliant invention, which had launched earlier in 1961, and Veroboard was destined to put home electronics construction within easy reach of hobbyists for decades to come. Readers faithfully followed the magazine's skilfully drawn assembly diagrams and soldered everything together with gusto.

The December 1964 edition encouraged hobbyists to use the new British-designed 'Veroboard System' to assemble circuits

There was plenty for the electronics enthusiast to see and do in this exciting new hobby, and the reader response to early issues of the magazine was immensely gratifying. Clearly, *Practical Electronics* was a magazine just right for its time, and its resourceful and focussed readers devoured its contents every month. The title was also keen to welcome newcomers and much attention was given to explaining the principles and physics of electronics to readers using easily digestible articles and tutorial series, starting with *Beginners Start Here* in Issue 1. Eagerness to educate would become a core value of the magazine and is still with us today.

Advertising

Practical Electronics also carried many fascinating advertisements that formed the critical backbone of the hobbyist's supply line. In Issue 1, an embryonic Sinclair Radionics Ltd advertised a 10W amplifier (the Sinclair X-10) and the Sinclair Micro-6 ('the smallest radio set in the world'), whilst Heathkit had a British catalogue of test, audio and radio equipment that were sold in kit or assembled form – £18. 18 shillings

The first advert in Issue 1 from Sinclair Radionics, whose DIY kits were already moving towards miniaturisation

bought a 'deluxe valve voltmeter' kit. Many home constructors sent for a Henry's Radio catalogue, the London-based mail-order component supplier being a lifeline for many constructors in these, the glory days of the hobby. Henry's advertisement graced the back cover for many years, while inside the magazine, the pages were crammed with myriad advertisers whose tantalising merchandise was just a phone call or mail-order coupon away. E-commerce was thirty years distant and so everything was handled by post or (if you were lucky) a local electronics or radio surplus shop might meet your needs. At one point, such was the terrific demand for magazine space in *Practical Electronics* that advertisers were actually being turned away!

The February 1965 *Practical Electronics* carried a competition called 'Magic Boxes' and, with a two-guineas prize on offer, inquisitive readers were invited to reverse-engineer an electronic puzzle and write in with their solutions. Such was the enthusiasm that more than 500 submissions arrived in the following week's mail. Something else appeared for the first time in that issue: a throwaway line under the Magic Boxes heading exclaimed 'Ingenuity Unlimited!' and readers queued up to submit their own answers to the Magic Boxes conundrum. The title stuck, and *Practical Electronics* eventually adopted it for a column of readers' own circuit ideas. In fact, it was 'IU' that first sparked this writer's own interest in hobby electronics back in 1975, the December issue. Reader interaction, as far as there was any, was conducted strictly by letter post, which meant a two-month lead-time on the *Readout* letters page.

Sounds of the Sixties

Readers would have to wait until the October 1967 issue to see their first integrated circuit project. It used a four-pin

linear amplifier from Mullard as the heart of a record player audio system. Integrated circuits like these heralded (or maybe threatened, depending on your point of view) another revolution in electronics design and assembly. Just as there had been much rivalry between the thermionic valve and transistor camps of the electronics fraternity, the dawn of the IC era promised to challenge them further still. In the closing years of the 1960s, more IC designs appeared, this time using devices from Plessey. Engineers who worked for major British manufacturers such as Plessey, Mullard and Lucas, as well as lecturers and professionals all regularly submitted articles of the finest quality and their work often graced the pages of *Practical Electronics*, which helped the magazine to maintain its quality feel with an authoritative and dependable tone.

In 1968, a young Mike Kenward joined the team as a technical sub-editor, following a successful interview with Fred Bennett. The magazine's editorial masthead was very restrained in the early days; only the name of the editor, 'F.E. Bennett' appeared. Mike was soon contributing heavily to *Practical Electronics* and indeed was the subject photographed for the July 1969 cover promoting an Optical Remote Controller, a device that was supposedly wired directly to a TV chassis!

The publisher George Newnes was a part of the International Publishing Corporation, founded in 1963 along with Odhams Press and Fleetway Publications. In 1968 IPC Magazines was created, its name appearing discretely under the Editorial of *Practical Electronics* from that moment on. Since IPC claimed to trace its roots back to 1853, it seemed to bode well for a magazine title's longevity!

A young member of *Practical Electronics'* Editorial staff – Mike Kenward – on the July 1969 cover, promoting an optical remote control system for TVs

Digital electronics and the 1970s

Into the new decade of the 1970s, and what lay in store for the electronics hobbyist? The answer came in the December 1970 issue with the title's first digital IC project – the *Digi-Clock* by RW Coles. This complex design used no less than 20 TTL logic chips and four cold-cathode tubes for a digital display. 1971 saw some highly significant designs being published, including the *PE Aurora* (April 1971) sound-to-light system, a design at last made feasible by semiconductor mains switching, and the *PE XEE* (June 1971), a sensory buggy which was hailed by BBC TV's Tomorrow's World as a sign of things to come in the technology world. Not every project turned out to be viable, though; a long-running DIY desktop digital calculator – the *PE Digi-Cal* (July 1972 onwards) was built with TTL logic and took no less than eleven monthly articles to complete, Unfortunately, it was obsolete almost before constructors turned off their soldering irons because single-chip calculators came onto the market around that time.

Another milestone was reached in June 1973 when a small new Signetics integrated circuit was announced to the *Practical Electronics* readership: the NE555V timer. This deceptively simple little 8-pin marvel became a staple item in every hobbyist's tool chest – and 40 years on it still is.

The advances in linear and digital dual-in-line ICs were unstoppable, with data sheets and application notes from Texas Instruments, National Semiconductor, Motorola and many more signposting the way that the industry was headed. Hobbyists followed hard on their heels, and interest in hobby electronics showed little sign of abating, helping *Practical Electronics'* circulation settle at a healthy 95,000 copies a month.

Success and the rapid pace of change could be a headache. Projects, tutorials and adverts all jostled for space, as ever-more advanced designs of astonishing complexity (for a hobby magazine) appeared, including CCTV cameras, electric organs and pianos, analogue computers, music synthesisers, electronic ignitions and a plethora of technically ambitious projects. There are far too many projects to mention, but the *PE Scorpio* ignition system and *PE Gemini* stereo amplifier are just two of many much-loved, outstanding efforts by their freelance contributors and the advanced hobbyist was spoiled for choice. Many of these key projects are remembered with fondness by their constructors to this day.

An everyday answer

There were so many new and exciting developments in microelectronics to explore in the 1970s, plus ever-more challenging projects put into print that competition for column inches was unrelenting. It became clear that it would be hard for *Practical Electronics* to continue to cater for all abilities and the journal risked spreading itself too thinly. Interest also came from the education sector, as schoolteachers and lecturers welcomed the support and value that *Practical Electronics* offered to their classes of budding electronics hobbyists and trainee engineers.

It was realised that even a simple two or three-transistor circuit could be very challenging for a beginner to tackle successfully. Often, transistor pinouts and diode orientations were a great mystery for novices, and there was no World Wide Web to provide technical data. In fact, suppliers' mail order catalogues were much prized for the component data that they (hopefully) contained. The desire to satisfy the needs of the higher end of the scale of abilities, while also endeavouring to cater for beginners and newcomers undoubtedly put pressure on editorial resources.

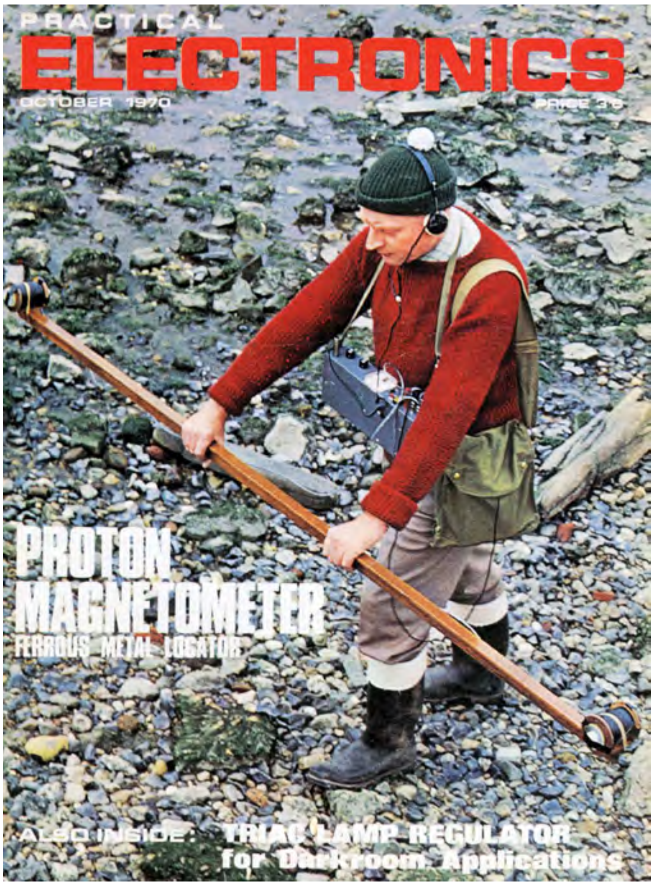
Everyday Electronics was aimed at novice electronics hobbyists when it was launched in 1971. The introductory November issue included a free gift of Veroboard

As a result of this need to cater for a wider scope of readership abilities, in 1971 the team behind *Practical Electronics* decided to spin out the more basic, entry-level content into a new journal to be run by the same team. Thus, *Everyday Electronics* was born, promising ‘Projects easy to construct and theory simply explained’. Its first November 1971 issue (price 15p.) offered some simpler home projects for the less-experienced hobbyist to tackle and a small pink paper envelope contained a free piece of Veroboard. The contents of *Everyday Electronics* were deliberately unintimidating, easily assimilated and well presented, sufficient to encourage the novice to have a go with confidence. A *Windscreen Wipe Control*, *Home Sentinel* opto switch, a *Snap* electronic game and a record player were all on offer. Apart from *Shop Talk* (component buying advice, written by a young Mike Kenward) there also appeared Part One of a ground-breaking electronics educational series called *Teach-In* by Mike Hughes, who started by offering readers some sound soldering advice. From the first issue, *Everyday Electronics* was already finding its feet.

Into the mid-1970s and *Practical Electronics* led the way again, this time with a design for a *Proton Magnetometer* ferrous metal locator. The article was characteristically comprehensive in its coverage of theory and practical assembly, with all diagrams expertly drawn by hand throughout. The issue was also notable for its cover photo of editor Fred Bennett, using the device on the banks of the River Thames.

Pong!

Another revolution was also under way in the 1970s, this time on our TV screens. Television



The founding editor of _Practical Electronics_, Fred Bennett, seen here trying the _PE Proton Magnetometer_ on the banks of the River Thames in London

viewers were mesmerised by the sight of a little white square bouncing around a blank screen and darting to and fro, with two users able to bat it back again using a simple control. Television video games had been born, starting with tele-tennis or ‘Pong’. There had never been anything like it, and enthusiasts of tele-tennis were soon glued to their screens into the small hours of the night. Dedicated integrated circuits were now being released that dispensed with the need for boards full of logic chips, although some of the IC solutions were buggy and much work was needed to improve the reliability of this latest wave of semiconductor chips.

June 1977’s *Practical Electronics* had a *TV Sports Centre* on the cover, showing Production Editor Dave Barrington eagerly playing tele-tennis with, he told me, a secretary borrowed for the photoshoot from IPC staff. July 1978’s issue had the more complex *PE TV Game Centre*, which promised 14 games of digital TV entertainment, although none of them looked anything like the motorcyclist or tennis player depicted on the cover! Primitive cartridge-based TV game consoles appeared in the shops for the first time and colour arcade games in pubs (the rest, as they say, is history).

Next month

In the second part, more advances in electronics technology are celebrated starting with the new age of home computing and then the single most significant digital device that changed the face of hobby electronics for ever. We trace *EPE* magazine’s heritage over the past 20 years, showing how Britain’s last remaining hobbyist electronic magazine has evolved from a number of competing titles. More fascinating cover shots of key issues are included, so be sure not to miss Part Two next month!

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Analogue-to-digital conversion on the development board

IN microprocessor development there are three areas that make engineers shudder with dread – interrupts, direct memory access (DMA) and analogue-to-digital conversion (ADC). ADC peripherals are generally the most complex on-chip peripheral that a hobbyist will play with, and certainly one of the least understood. So now that we have a nice stable development board, let's experiment a bit and develop some ADC support within our template code, while learning how this complex peripheral works 'under the hood'.

The peripheral block diagram is shown in Fig.1. There are two main parts to it; the converter itself, and the input multiplexer that allows up to 13 input pins to act as analogue input sources. (I'm not sure where you'd find 13 things to measure in a simple embedded project; if you can think of one, let us know!) Before delving any deeper into the inner workings of the peripheral we need to answer a key question: 'What does the ADC actually do?'

Bridging the analogue divide

Let's recap on some computer theory. Processors have a very simple life, having to deal with only ones and zeros. Lots of them, of course, and very very quickly, but still only two numbers. Internally, the PIC microcontroller represents a zero by the voltage 0V and a one by 3.3V (or whatever voltage powers your processor). This concept of ones and zeros extends to the device's input/output pins.

Engineering life is never that simple of course, and as engineers we accept and recognise that everything has a tolerance. A quick look at the processor datasheet reveals that the actual thresholds for maximum input-low voltage and minimum input-high voltage is complicated and differs between pin types. We generally don't bother looking at these values when we are connecting CMOS integrated circuits together because CMOS devices generally have the same switching thresholds, and operate by switching quickly from one extreme to the other. Digital signals do not dwell at the in-between voltages.

The real world does not occupy such a narrow, binary universe. External physical parameters, such as sound, light or temperature are converted and scaled into voltages that vary continuously across the complete range that a processor can tolerate: Vss to Vdd, or 0V to 3.3V on our processor. A temperature sensor, for example, may convert the sensed temperature into a voltage between 0V and 3.0V in a linear (or near-linear) fashion – there will be no discernible steps in values as temperature values change.

The processor's ADC peripheral's job is to translate these varying signals into something the processor can understand. There are two, slightly different converters in your processor; a 10-bit ADC and a 12-bit ADC. The former can represent an input signal as a value between 0 and 1023, the latter as a value between 0 and 4095. Why have two and why the minor difference? It's because the 10-bit ADC is much faster than the 12-bit one, and that speedier response may be more useful than the higher resolution. The value 0 represents the lowest possible input voltage, 0V, while 1023 (or 4095 for the 12-bit converter) represents the highest.

Two input pins Vref– and Vref+ allow the converter to have a different 'lowest' and 'highest' reference point, but we have not yet found a use for these, and instead connect them inside the processor to Vdd and Vss. One benefit of supplying Vref+ externally is that you could isolate it from the processor's digital supply rail and reduce the amount of electrical noise present – more on that later.

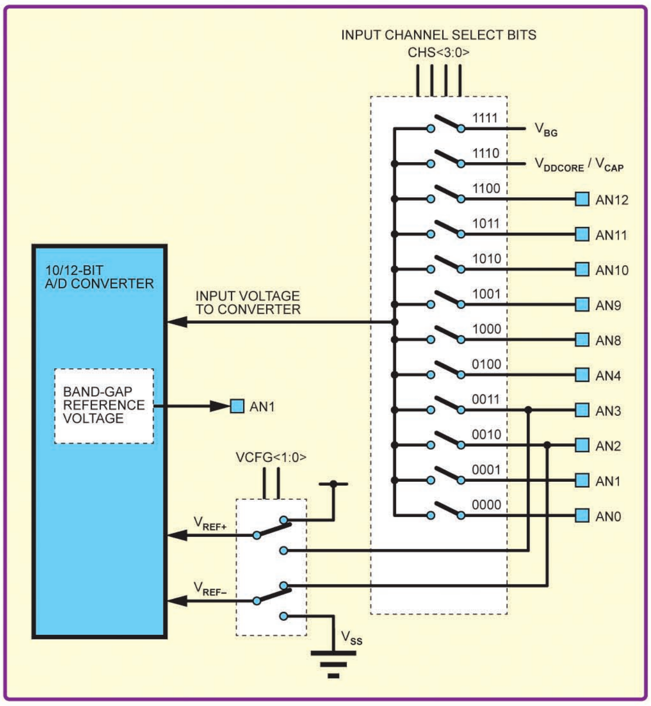


Fig.1. The ADC peripheral

Many inputs

The ADC can accept up to 13 analogue inputs, but only one input can be measured at any one time. The measurement is quick, however, and so it is reasonable to have several inputs active and to rapidly cycle through them in turn. This is why the ADC peripheral has a multiplexer, to route one of many inputs to the single ADC converter. The analogue inputs are themselves multiplexed with other digital I/O pins, with the pin being used for only one purpose – digital or analogue, never both.

The converter itself is shown in Fig.2. This is a successive approximation converter; a digital-to-analogue converter (DAC) is employed to create a reference voltage that is compared, via an ordinary comparator, with the input signal. A 10- or 12-bit register is used to search up and down for a reference voltage that, at the toggling of the least-significant bit of the DAC bisects the input signal. It's a simple circuit, but relatively slow, although perfectly acceptable for many hobbyist and general control designs. The 10-bit converter can run at up to 100,000 samples per second, easily sampling audio signals. A clock signal derived from one of the processor's many clock sources drives the conversion register.

A key part of the peripheral is the sample-and-hold circuit. It's reasonable to assume that the input signal will be changing rapidly with time, which would play havoc with the ADC's 'search' for the appropriate value to place in the DAC. To avoid this, the input signal is routed to a capacitor,

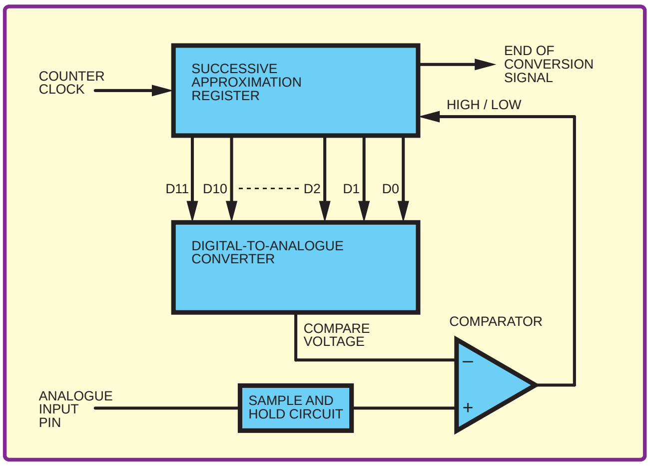


Fig.2. The analogue-to-digital converter (ADC)

which is charged up for a short amount of time (being careful to ensure enough time is allowed for the voltage on the capacitor to reach the input level) then the input is disconnected while the conversion takes place. The times involved and the frequency of the ADC clock is all under the control of the software engineer. So as you can already see, it's a complicated little peripheral.

Sources of error

Dealing with signals in the analogue world means we have to start dealing with noise. Noise is rarely an issue in the digital world because the two signal levels are well separated; not so with analogue. There are many types and causes of noise, and each has it's own peculiarities and it's own approach for solution (although you can never remove noise completely, only make it less of an issue.)

Input signal noise – unwanted signals that appear on the input being measured. If at frequencies far above or below the frequencies of interest, they may be removed with analogue or digital filters.

Reference voltage noise – if the input signal is constant but the reference voltage is changing due to noise, then the apparent input voltage will change too. The reference voltage may be routed to its own pin and heavily filtered, to minimise variation.

Quantisation error – the DAC in the ADC peripheral may not have a perfectly linear response. It also has a finite step function, where several voltages that differ slightly return the same value. These cannot be so easily filtered out, but they may be compensated for by calibrating the parameters of each individual IC.

Finally, don't forget it's always possible to improve analogue-to-digital conversion by using an external ADC circuit. ADC peripherals on microcontrollers are not renowned for their accuracy; residing on an IC and sharing real estate with other high-speed digital circuits means interference is inevitable.

Mode of operation

An ADC peripheral has two modes of operation – polling, where you wait in a loop for the sample to become available, and interrupt, where you start the ADC conversion but then continue doing something else until the conversion completes. Interrupts are, of course, scarily complicated things to be avoided, but this is one time where they are very useful. An ADC conversion can take many tens of microseconds to complete, and that's a long time to be hanging around waiting for the conversion to complete. In many cases this is not an issue – the code cannot do more until a value is returned, in which case waiting is not a problem. Interrupts will, however, provide a greater degree of flexibility. I recall one example: I was reading three input signals (temperature and two voltages) averaging them over time and signalling to the foreground task with a bit in a register when the values changed too much. All of this was done in the interrupt routine, which only triggered periodically for a very small amount of time to start the conversion, the program returned on the next interrupt to read the value, generate a running averaging, and setting a bit if there was a problem.

Typical uses

As we mentioned earlier, the ADC has a wide range of uses. Connected to a cheap sensor it can be used to measure sound, light levels, motion (from a PIR sensor), temperature and vibration, as well as the obvious examples of voltage and resistance. There are many different uses, but ultimately it is all about measuring voltage.

One great use is monitoring your own battery voltage, in particular for low power or solar-powered circuits. The processor can make some intelligent decisions about when to activate power-hungry circuits such as a Wi-Fi interface: if the power level is low, delay until the battery has charged up, or turn off some other power-hungry device.

Putting it to use

We will experiment with our ADC using a simple trimpot, as it is an easy way to set up and control the peripheral. Fig.3 shows the circuit we will construct, a simple expansion on last month's breadboard setup. We've opted for a 47k trimpot, but the value isn't terribly critical.

Next month

Next month, we will look at the code to control the ADC and provide some useful functions for our development board template code. Plus, if there is time, we'll start on the versatile PWM module. We will make use of the LCD display to monitor the ADC's readings and investigate the impact of noise, and what we can do about it.

LPLC – just how low can we go?

I was asked recently what the minimum current consumption of the LPLC board actually is. I was being taken to task on the fact that I had referred to the board as 'low power'

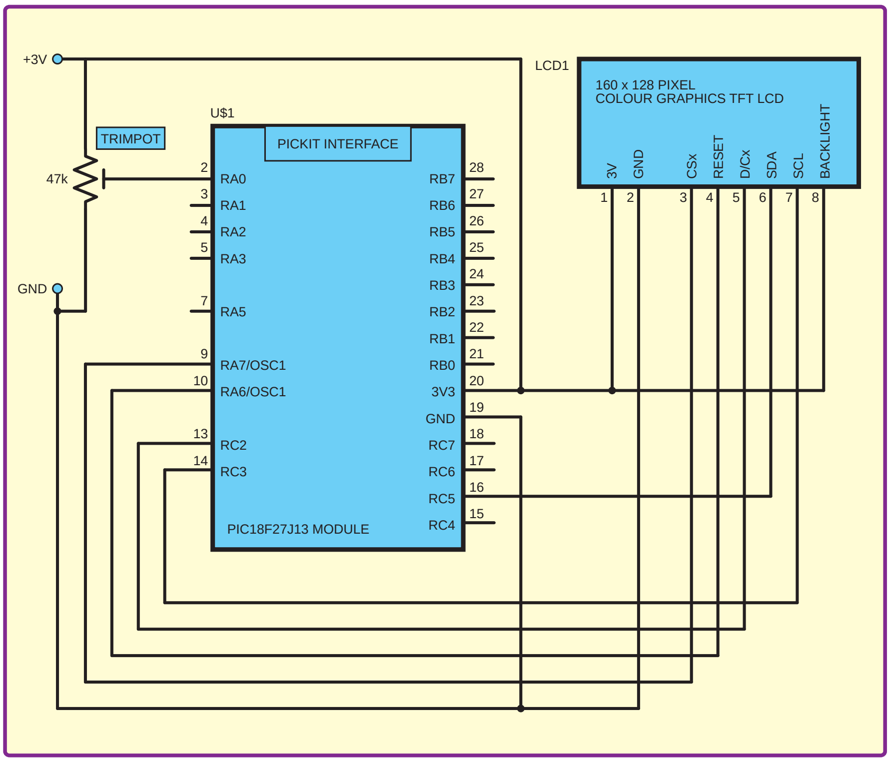


Fig.3. This month's circuit diagram

without properly qualifying the statement, or backing it up with a practical example.

My glib answer was 'zero, when it's turned off.' That's not terribly helpful because the processor is incapable of doing any useful work, but it does highlight the point that 'minimum current consumption' really depends on what the device is doing at the time, and what you are expecting of it. So let's work from a real-world example: the processor is monitoring the temperature reported by a simple sensor, and transmits its readings via a Bluetooth transceiver back to a central server. In this scenario the sensor is being turned on briefly every 10 minutes, and the Bluetooth transceiver eight times a day. Under these conditions we are able to ignore the current of the sensor and transceiver as they are being held in a powered-down state when not in use, and their small (average) current consumption negligible.

We are therefore looking at what current consumption the processor takes when it is only waking up and doing something useful every 10 minutes, for perhaps a few milliseconds. Under these circumstances we can ignore the 'active' current during these few milliseconds, as it contributes such a tiny average current consumption to the overall figure, just as for the other two components. Our operating requirement is a timer that can allow us to put the processor into a low-power mode (turning off the main oscillator) and when the timer expires the main oscillator restarts and the CPU can run as normal, before returning to low-power mode again.

The normal technique here would be to use the external watch crystal oscillator fitted to the board. That's not a bad idea – it's why we fitted it in the first place. It draws a few tens of microamps, which is pretty low, but we can do a lot better.

We can improve matters by acknowledging that our 'wake up every 10 minutes' does not need to be terribly accurate. Now, we can make use of the 'Ultra Low Power Wake-up' feature of this processor. To use this mode, a large value capacitor is connected to one of the I/O pins. The pin is driven high to charge the capacitor; the pin is then turned into an input and the processor put to 'sleep'. The charge on the capacitor will slowly decay, and when it falls below a certain point, an interrupt occurs and wakes the processor. Under these conditions the processor will draw a current of just 60nA.

The fact that it will not be terribly accurate is not a problem – if you need improved accuracy, then 're-synchronise' your clock when your Bluetooth module re-connects to the server.

Not all of Mike's technology tinkering and discussion makes it to print. You can follow the rest of it on Twitter at @MikeHibbett, and from his blog at: ***mjhdesigns.com***

NET WORK

by Alan Winstanley

IoT update

LAST month's *Net Work* mentioned the 'IoT' (Internet of Things) – the latest buzzword describing the integration of all sorts of devices with the Internet. Obvious contenders include cameras, lighting and security systems that operate over IP, enabling them to be controlled from a tablet, smartphone or other web-connected device anywhere in the world. Even in the early days of *Practical Electronics* (see the separate feature in this issue, celebrating 50 Years of *PE*), designers dreamt of remote-control gates, garage doors and appliances and the IoT will start to make it simpler to integrate these devices together using a networked environment. As mentioned last month, Google estimates there will be 25 billion such devices in the near future, and manufacturers are lining up in various groups to create their own vision of how they think the IoT will evolve. Sony is the latest to join such a group (the Allseen alliance).

Making bacon

I also mentioned Dropcam, a fixed wireless remote camera system now owned by Nest (in turn, by Google) that functions over the cloud. It offers HD imaging and night vision, two-way sound, alerts and video recording (a paid-for service, currently US only) so that footage can be wound back and viewed. This latter feature worked brilliantly on the Freedom Farms demo (now offline) that I described in October's issue. A farmer set up a Dropcam in a pigpen where an expectant sow was getting ready to produce her litter (see page 47, October *EPE*). I duly kept my eye on it through the day, but the happy event took place overnight (UK time) because next day a litter of piglets had already appeared right on cue! The Dropcam program allowed earlier footage to be skipped through and the deliveries of delightful piglets could be observed: all ten of them.

Overall, the Dropcam demo system worked extremely well. US users can opt for 7 or 30 days' worth of storage at a monthly or annual cost (typically $10 or $30 per month). Other demos can be viewed at: **https://www.dropcam.com/live-demos** – do remember to make allowances for time zone differences. I'm currently watching a busy-looking T-shirt printing firm starting up in the morning and a timeline enables the video to be scrubbed back and forth.

Dropcam has a 107° field of view and 4× zoom, whille Dropcam Pro offers 130° and 8× zoom. In the UK they can be bought from Amazon, which is always a useful source of customer feedback: reviewers confirmed that the IP camera cannot work with the BT Home Hub. Other Wi-Fi cameras include the Philips Insight (for iPod, iPhone, iPad only – no Android here) and users report problems with software upgrades knocking out its ability to upload images to the Dropbox hosting service. This type of disgruntled feedback has a certain recognisable ring to it: my own trials of a typical unbranded wireless PTZ (pan-tilt-zoom) camera in *Net Work*, September 2012 were barely successful, mostly due to wireless and software problems. In short, the device did not perform as well as expected. Another idea might be to add a Wi-Fi repeater, or a Develo-type system to run a network through the ring mains. This might be better for connecting an Ethernet-enabled IP camera instead of relying on troublesome Wi-Fi.

Storm clouds

Cloud-based devices like Dropcam and Insight show the way home automation is moving. With emerging technology it is often the case that early adopters endure the teething problems and become guinea pigs for the next wave of users – it was ever thus. Earlier this year the sonic alarm of the £89 Nest Protect wireless smoke and CO detector (see last month) was found to have the unfortunate feature of potentially being disabled when passers-by waved at it (see **https://nest.com/letter-from-the-ceo**). Sales were suspended for a few weeks while a fix was designed, but one benefit of the IoT was that a Nest Protect could be patched over the web. Those with no Internet access who could not update their Nest were offered a complete refund. Sadly, some recent reviews by customers have been scathing both of Nest Protect and its UK-facing customer service: one user gave up when his Nest supposedly messaged him twice to say his kitchen was on fire, and multiple users report worrying problems with reliability. Discerning buyers will want to sift through customer feedback first before taking the plunge.

File associations

Back down to earth and the present day, and the topic of downloading and viewing PDFs cropped up on the *EPE Chat Zone* recently. Regular *Net Work* reader ***Paul Bowden*** wondered about file associations and a problem he recently noticed – many files on his PC desktop suddenly changing their icons to Firefox. For web surfing Paul had sensibly ditched Internet Explorer (stuck at insecure Version 8 on a Windows XP machine) in favour of Firefox. (Google Chrome is another more-secure alternative to IE8.) However, Paul's large array of PDFs now sported the furry Firefox symbol instead of the Adobe PDF icon that we are accustomed to seeing. The Firefox browser itself, Paul added, ground to a halt whenever he tried to access these files and he wanted to revert to pre-Firefox bliss.

Rather than Firefox being entirely to blame (although hijacking PDF icons was a bit rude!), clearly there was a problem with Windows file associations in his XP machine. These instruct Windows to open a particular file type with your choice of program. By default, PDFs usually open with Adobe Reader, if installed. Associations can be changed via the XP Control Panel/Folder Options/File Types tab, which lists all the file types and their associations. In Windows 7, choose Default programs from the Start button to access associations. Other programs can, however, be chosen for the default, such as Foxit Reader (**http://www.foxitsoftware.com**) as another user recommended.

There are differences between opening a PDF directly from within the browser, which can be a bothersome process, if it works at all, and opening it outside the browser using a PDF reader, which is probably a slicker option. Plug-ins or add-ons for browsers allow them to directly open PDFs, but *Chat Zone* user ***twintub*** added a handy note for Chrome users: *Even if 'file associations' are correctly configured, the Chrome*

browser will still (by default) open PDFs within the browser. To correct this undesirability, type 'chrome://plugins/' (without the quotes!) into Chrome's address bar, scroll down the list to find 'Chrome PDF viewer' and click on the word 'disable'.

Unfortunately, the PDF format is about as secure and watertight as a basketful of alphabet soup. These supposedly inert files can host some very dangerous malware scripts and exploits. This has caused Adobe Reader to be patched with monotonous regularity. In *Net Work* July 2014 I outlined the jargon of 'Common Vulnerabilities and Exposures' (CVEs) – security threats posed by files and software – and how CVEs are classified by the US Government. CVEs are used to index any significant Internet or software-based threats for reference purposes. An 'exposure' is defined by the CVE Initiative as a configuration problem or a mistake in software that could allow hackers access to a system or network. A 'vulnerability' is defined as a mistake in software that can be directly used by a hacker to gain access to a system or network. This could let an attacker execute commands, or access data, or pose as someone else, or conduct a damaging denial of service attack.

One way a vulnerability can be exploited is through a 'back door' on a server's system that permits unauthorised access to the rest of the network. I suffered such an attack on a shared web server when an outdated program used by another website owner had a bug that allowed a hacker to access all the other websites hosted on the same web server. Their home pages (including some of mine) were replaced with one uploaded by the hacker, wrecking scores of websites in the process. Unfortunately, many popular server-based programs (notably forums and shopping carts) need constantly patching to guard against this, which has become an onerous but necessary job for the vigilant systems administrator.

Potentially dangerous files

With PDFs in mind, a quick glance at: **www.malwaretracker.com/docthreat.php** lists a number of likely threats posed by infected documents and files, including Microsoft Office Excel, Flash files and PDFs. It can be seen that PDFs can play host to numerous potential threats. Links to the CVE database are provided, and an online document scanner is offered at: **www.cryptam.com** if you want to scan a file over the web.

If PDFs are routinely treated as harmless, then infected ones can allow malicious hackers to do extreme damage, for example by launching scripts that access systems or encrypt precious data files. Payments can then be demanded to release them (so-called ransomware). The highly damaging 'Cryptolocker' malware is the work of a Russo-Ukrainian gang and can be distributed via infected PDFs, typically in the shape of phoney shipping documents sent to corporate addresses. Opening them would install a 'bot' and also enrol the host system in a global botnet capable of redistributing the malware as well as stealing online banking credentials.

It is estimated that a quarter of a million machines were infected by Cryptolocker and nearly $30 million in ransom money paid before the FBI and other agencies in 'Operation Tovar' took down a major part of the botnet. To undo the damage, a payment of typically $300 or €300 had to be paid in order to access the private key that unlocked the encrypted files. A countdown timer showed how long this lifeline was open for, after which the heavily encrypted files would be lost forever. Perversely, it was also reported that even when ransoms were paid, the unlock key might not work.

A number of companies are offering victims of Cryptolocker free help to unlock their files, notably a partnership between cyberthreat specialists Fireye and Fox-It. Visit **https://www.decryptcryptolocker.com** for details. A trusted website always worth checking for answers to virus and other IT problems like Cryptolocker is **www.bleepingcomputer.com**.

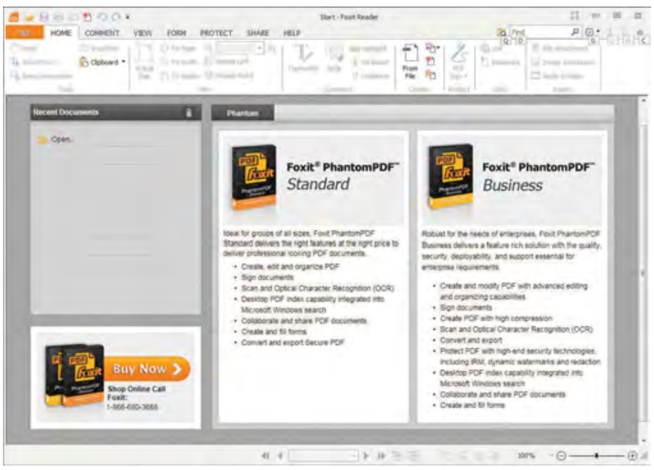
How can users guard against such attacks? The obvious answer is to be vigilant and watch closely for suspicious emails arriving on your phone, tablet or computer, especially emails that carry .zip files or PDFs. Many phishing emails are authentic-looking, but they usually start with 'Dear User' or 'Dear Customer' because the spam email databases are unable to merge the user's name – not yet, anyway. Particularly soft targets are inexperienced users on a home network who might receive such files and innocently open them, so take a moment to explain the risks to others and highlight the warning signs (if not the dangers) to prevent any virus damage arising.

Windows XP – a little more time left

With Windows XP users in mind, the next step is to maintain up-to-date anti-virus software, which is likely to become a problem for elderly XP machines after another year or two. Until then, free software such as AVG or Avast can fill the gap in online defences. I estimate they have a 50% chance of catching something. For free software, my preference is currently Avast (**www.avast.com**) which is easy to use, although it caused one of my XP machines to crash – but it runs fine on another. Avast was used to replace paid-for AVG, which on my system proved very troublesome to un-install until the AVG removal tool was used, and then it would not re-install properly. Many passes of CCleaner were needed to clean the Registry of debris.

Another line of defence is SurfRight's Hitman Pro, which calls itself a 'second opinion malware scanner' that works alongside your existing software. A free plugin called Hitman Pro.Alert runs with the web browser and guards against banking Trojans. Unfortunately, this caused a blue screen on my XP machine. See **www.surfright.nl/en/alert** and consider the paid-for version of Hitman Pro, which will also offer to create a 'Kickstart' USB key to boot your PC if it is blocked by ransomware.

The time is fast approaching when an older Windows XP system will become too frustrating, slow, insecure and unrewarding to use, when new software brings a PC to its knees and that will be the time to finally move on and invest in an all-new machine. Until then, I'm going to try re-installing AVG yet again, and marvel at why its digital TV card no longer works, the browser locks up, Java needs re-installing and my PC keeps rebooting all by itself. You can email the author at **alan@epemag.demon.co.uk**



Foxit Reader is an alternative program for viewing PDFs

Hitman Pro is cloud-assisted anti-malware offering a free scan and a free browser alert plug-in

MAKE YOUR OWN PCBs

Part 3

Mike Hibbett looks at how to produce your own printed circuit boards (PCBs). In Part 3 he uses EagleCAD software to create a simple single-sided design.

WE have the perfect exercise for our EagleCAD experiment over the next two months – first creating a simple, single-sided through-hole board that you can create yourself at home (assuming you have etching equipment available) then the following month creating a surface mount board that we can (and will) send off to a PCB manufacturer.

Our choice of board designs are not random, but are actually the components of my home made 'Open Source Drum Kit', which I demonstrated at the Dublin Maker fair back in July. The electronics for that were a prototype made up as I went along, so this is an excellent opportunity to kill two birds with one stone – explain PCB design and smarten up my design before I publish it in the public domain.

The drum kit is an ideal project for a PCB design, as it covers some of the key reasons for using a CAD program:

- Documenting your design – it's great for documenting your designs, rather than drawing on scraps of paper.
- It's easier to re-use parts of the design elsewhere.
- A PCB produced from a CAD design will be more robust, tidier and more attractive than a hand wired board (even if you make the board yourself.)
- You will save time in the long run if you are building several boards because it is significantly quicker to assemble a PCB than doing point to point wiring on a prototype board.
- Sharing your designs with others becomes easier; you can email the raw CAD data or convert the design into a PDF document or a jpeg image.

The drum kit consists of a control board holding the micro SD media card, processor and audio amplifier. You can see the 'rats nest' prototype in Fig.1. Being a prototype, it's clearly over engineered with an LCD, four-button user interface and an array of ¼-inch jacks for the inputs. Each input has a standard signal conditioner to ensure that the output of the drum pad transducer – which can peak at ±30V – does not damage the microcontroller.

This setup was fine for a prototype, but it revealed several flaws. The LCD and keypad were unnecessary; only two buttons are required, at most. The ¼-inch jacks are large and an expensive way to connect to the drum pads; it will be simpler, smaller and cheaper to use screw terminals. Placing the signal conditioning circuits on the board was a bad idea too. Having a fast-edged 30V pulse running down a wire next to a bunch of others caused amusing cross talk, triggering several drums at once. It will be better to have the small circuit on its own PCB, right next to the piezo sensor on each drum.

It's this small signal conditioning circuit that we will create this month. We are using standard through-hole

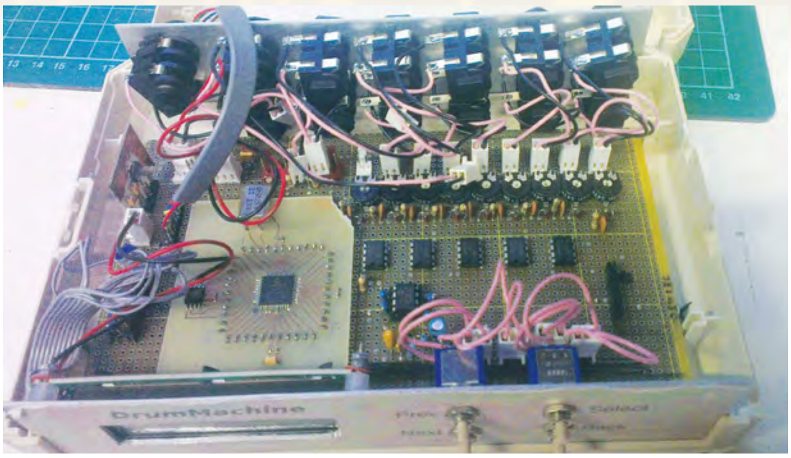


Fig.1. Drum kit controller board

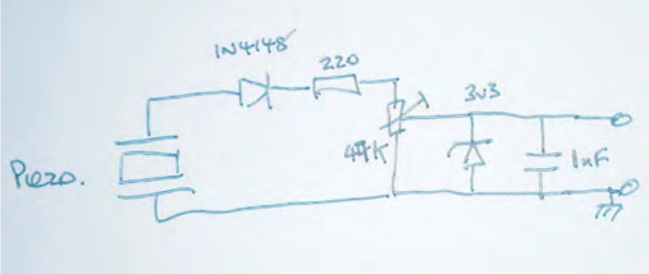


Fig.2. Hand-drawn conditioning circuit

wire-ended parts, and will focus on making this board single sided and easy to assembly by hand. The hand-drawn circuit is shown in Fig.2, and you can see the pile of parts that will be used in Fig.3. To help keep costs to a minimum, the screw terminals are optional; you can simply solder wires in place. Although at a cost of about 50p each, it's probably worth the investment for the flexibility of being able to easily attach and detach the drum pads from the frame.

We are going to design a single board in EagleCAD, but when it comes to actually making the board we will make eight of them on a panel in a 2 × 4 arrangement. We'll do this by simply printing the artwork out eight times. We're not going to cover the details of etching your own boards – that merits an article in its own right – but we will show you the finished board next month.

One of the nice things with designing a board with normal, through-hole components is that the CAD symbols for the parts almost certainly exist in the EagleCAD library. It's important to be careful with the symbol you choose for a part – make certain you have the right one. Resistors, for example, have different body lengths, and as the power rating goes up so does the thickness of the lead. Diodes too – a 1N4148 is very different to a 1N4001. We've been caught out several times, and needed to re-drill holes slightly to accommodate a larger wire. Some axial capacitors come in a metric 5mm spacing, while others come in a 'metric version' of a 0.2-inch pitch (actually, 5.08mm), which can 'fit', but not quite properly.

Over the years, I've settled on the following technique: purchase the components *before* making the board, then measure the lead dimensions with a micrometer and verify them with the CAD dimensions. I even print the board design out on paper, then line the components up with the holes and pads to check all is well. This also helps ensure that the board design has been printed at the correct scale – it's very easy to select the 'scale to fit option', which is *not* what you want when printing a 1:1 scale image of your board.

Drawing the schematic

Let's start the EagleCAD program and continue from where we left off last month – having just created the empty schematic, as shown in Fig.4. We got here by selecting the **File** option from the Control Panel main menu, then **New** followed by **Project**. If you are following along, name the project 'SENSOR'.

Right-click on the word SENSOR and select **Open Project**, then right click on SENSOR again and select **New** followed by **Schematic**. Your view should be very similar to Fig.4, where a new window has opened up. We are now ready to start transferring our hand drawn schematic from Fig.2 into EagleCAD. Note the area in Fig.4, highlighted in green. This is EagleCAD's *command line*, where commands may be typed in. Some commands can only be entered by the command line; most, however, can be selected from the menus or from the icons above and to the left of the schematic entry window. Just remember, when we say 'type the command *xyz* on the command line...', we are referring to EagleCAD's command line. To enter a command you simply start typing text, and press the Enter key at the end.

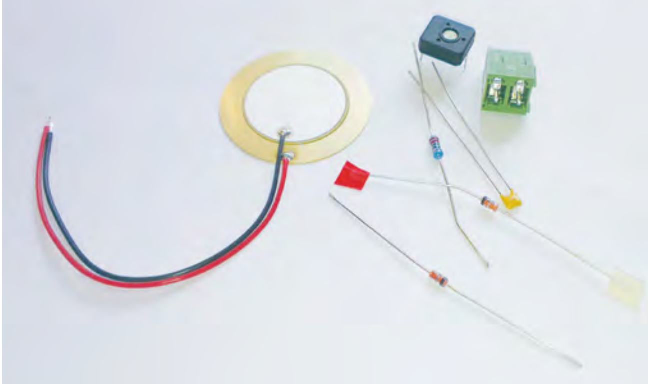


Fig.3. Drum pad sensor and the signal conditioning parts

We are going to add seven devices to the diagram: a two-pin header for attaching the piezo buzzer, two diodes, a resistor, trimmer resistor, capacitor and a two-pin screw terminal header. The idea is that the piezo buzzer will be soldered directly to the board on the pads of the two-pin header, but the cable connecting the pad to the drum controller will connect through the screw terminal. The board will be stuck to the back of the drum sensor with hot-melt glue so there is no point having a connector to the piezo buzzer.

In EagleCAD you place *devices* on the schematic; a device represents both the *symbol*, which you see on the schematic, combined with its *package*, which is the physical description of the real part. Some devices have multiple packages associated with them, which can be selected later on, but many do not. You must take care to select devices with both the correct symbol *and* package.

This can be quite a time consuming task, even when a suitable device exists. The problem is that the specific part number or even the manufacturer may not exist in the library. Instead, you have to search for something similar.

Let's take a look at EagleCAD's library and how we go about finding parts.

Finding our components

Leaving the schematic window open, click on the Control Panel window and click on the diamond to the left of the word 'Libraries' in the list of items, as shown in Fig.5. There are thousands of devices, all nicely organised in directories, but there is still a lot to go through. Thankfully, there is a search option at the bottom of the window. Typing in 1N4148 brings up the part, buried within the **diode.lbr** library. Note that there are two versions, one of

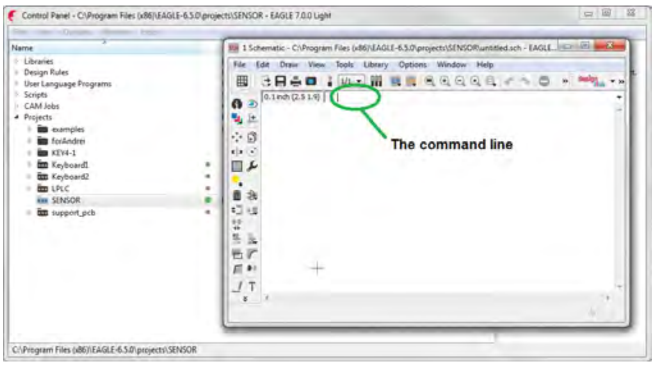


Fig.4. EagleCAD – ready for schematic entry

Fig.5. Library search

which has the holes slightly further apart to allow for a less tight bend on the component legs. That looks good, so we click ADD, which selects the part and brings us back to the schematic window. As you move the cursor around you will see the symbol of the diode beside the cursor. For now simply drop it into the window, anywhere, with a left click of the mouse. Then press Esc, followed by clicking Cancel to exit the ADD option.

We can cheat a little when selecting the capacitor and resistor; generic parts are found in the **rcl.lbr** library. There are two definitions for each: C-EU and C-US for example. This is to distinguish between the European and the US standards for what a capacitor and resistor should look like. It makes no difference which you use, but do be consistent. We've gone with the European version. Double click on the C-EU symbol to bring up a list of package options – the first one in the list looks right. Don't worry about double checking yet, as the device has a whole list of package variants which we can choose from later without messing up our schematic. (Deleting a component and adding a new one after you have drawn the schematic can be painful.)

The Zener diode is physically the same as the 1N4148, but has a different circuit symbol, so we need to find the appropriate part. Searching for the part number we used, 1N746A, didn't bring up anything, so it looks like we need to find a generic Zener device with the correct holes and spacing. Searching for the word **zener** first bring up a surface mount device, but the second result (found by clicking the **Next** button at the bottom right of the Library window) brings up a generic part with lots of packages defined. We selected the forth device in the list of packages, 'diameter 2mm, horizontal, grid 10.6mm) as this approximately matches what we selected for the other diode. Don't forget, there are lots of packages defined for this part, so we can easily change later.

The trimmer was harder to find. Once again, the actual part number we used – CITEC CB10LV473M – didn't exist in the library. A search for 'trimmer' and then 'trim*' eventually brought up something that *looked* right – TRIM_EU – in the **pot.lbr** library, using the CA9V package. We'll add it for now, but take a closer look once we get to laying out the board.

The two pin header is easy to find in the appropriately named **pinhead.lbr** library. The screw terminal header, however, required another detailed search. Looking for ***screw*** Brought up many, and by measuring our own part with a micrometer and comparing to the scaled drawing in the library we ended up with W237-02P in the **con-wago-508.lbr** library.

So that's all our components selected, giving us a schematic something like Fig.6. Let's go ahead and position them, then wire them up together.

Schematic layout

To move parts around, first left click on the **Move an object** icon, the third one down in the list of icons on the left of the window. Now left click on the device you want

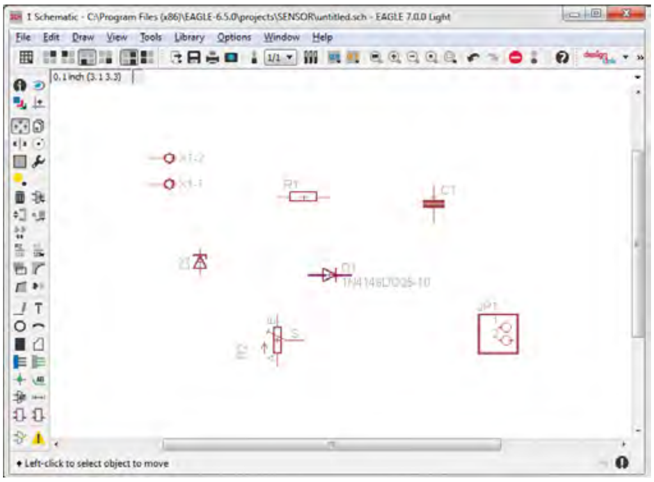


Fig.6. Components selected, ready for positioning

to move – it will change colour to indicate it has been selected. You can reposition it, clicking the right mouse button to rotate it if required. Notice that the component position moves in jumps as you move the mouse; this is because by default the components are aligned to a grid system with a pitch of 0.1-inch. You can move items with a finer positional resolution by pressing and holding down the Alt key. Our recommendation, however, is that you don't do this. Accurate placement of component and wire endpoints is necessary for EagleCAD to recognise your intent to join things together. Offset wires slightly and your diagram will look connected, but actually won't be. This can be difficult to spot, and will cause problems with the board layout later on as EagleCAD will not complain about an unconnected output pin or two.

Position the components as per the hand-drawn diagram, leaving space between the component leads – don't butt the components up to each other in an attempt to avoid adding a wire – the wire is a useful addition because it can be given a name and can be viewed on the board layout. Fig.7 shows what we mean.

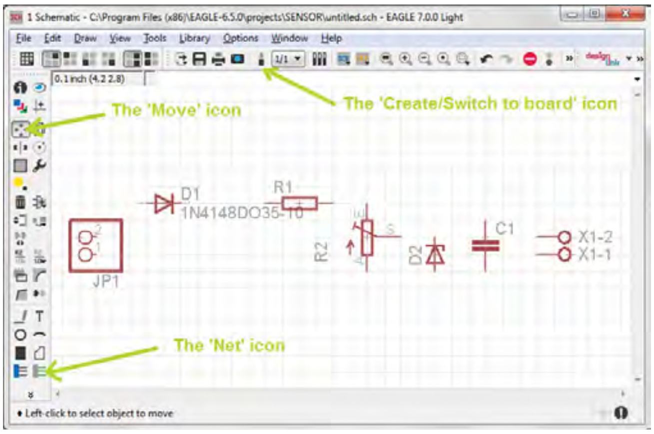


Fig.7. Components placed, ready for wiring

Now let's complete the schematic. To draw the wires select the 'Net' icon, *not* the 'Line' icon. Lines are simply visual aids and are not electrical connections.

Left click the mouse at the point where you wish to start. Click again when you want to make a fixed 'bend' in the wire, then click at the destination point to finish. Normally, EagleCAD will recognise you have reached an end point and stop the wire command; if not, simply press the Esc key. To start another wire, left click again. It took only a few minutes to arrive at the finished schematic in Fig.8.

Now we give the components their values. Left click on the 'Value' icon and then click on each component in

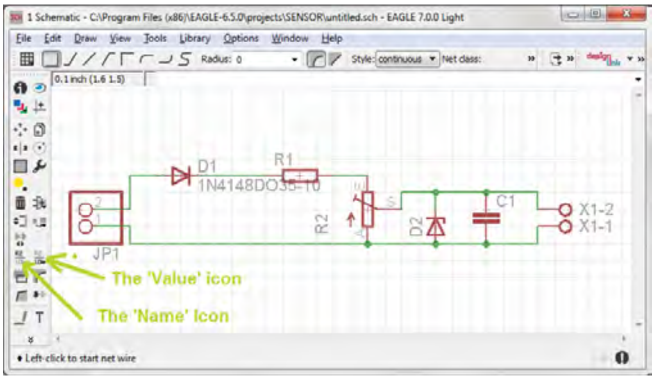


Fig.8. Fully wired schematic

turn, entering its value. Do this for D1 too (even though it says there is no user defined value) so you can enter the shorter value 1N4148. Complete the schematic by selecting the 'Name' icon and then clicking on the GND, IN and OUT wires to give them more meaningful names. You can use the 'Label' icon to reveal the wire's name, and position it on the schematic.

Now it's time to create the board. Click on the 'Generate/Switch to board' icon, and answer 'Yes' to create the board. You will be presented with the image in Fig.9. There is a square on the right, indicating the outline of the maximum board size available to the light version of eagleCAD (100mm × 80mm) and the components have been dropped at the bottom left. They have not been placed in any useful order – it's up to you to position them as you see fit.

As you move the components you will see light coloured wires attaching them; these are called *airwires* and they indicate lines of electrical connection. These are not copper tracks, just an indication of where you will need to make the tracks – it's up to you to add them later. We ended up with a compact rectangular design shown in Fig.10. The rectangular layout is more efficient on board space – it's denser, wasting as little material as possible – and it is also likely to be sturdier than a long, thin PCB. The choice is yours, of course.

Auto routing

We now have two options for creating the tracks between the components: the AutoRouter or manually routing each airwire. You can see the result of selecting the AutoRouter in Fig.10. It's worked, but the tracks are thin, run close to components and there is a lot of copper that needs to be etched away – this is not a great solution for home etching. It is, however, a good hint at how the signals should be routed – so we take a screen capture of that board layout, then rip up the tracks back to air wires. After shuffling a few components around we ended up with the layout shown in Fig.11. This is our completed design – to produce a board from this we would simply turn off the layers that we do not need to be present (leaving just the bottom, pads and dimensions visible,) print to an overhead projector sheet and etch a board in the normal manner. As we needed eight of these we simply printed out further copies and placed them on a single sheet of photoresist PCB. A board of this style is also suitable for the Press and Peel transfer system if you don't have access to an ultraviolet exposure box.

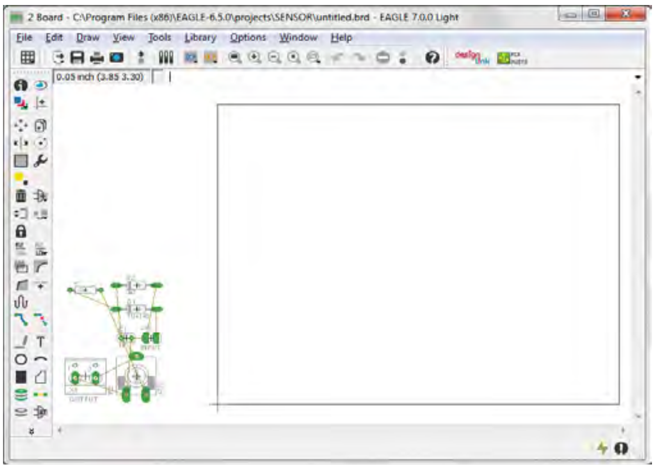


Fig.9. Board creation window

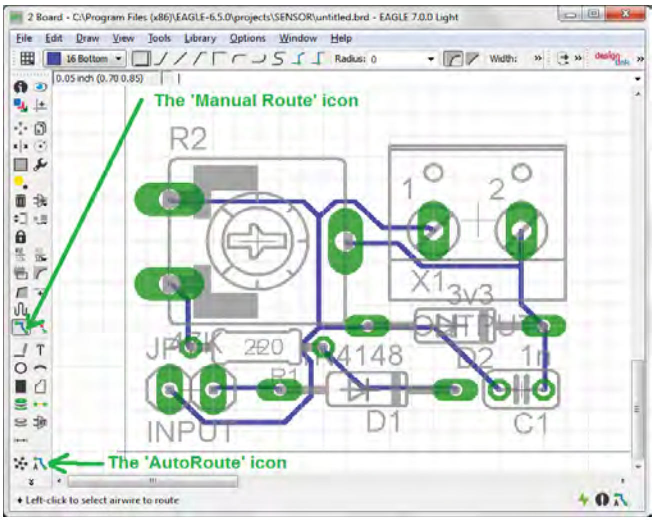


Fig.10. Component placement

We will show the completed board next month, but in the meantime the full CAD files for this design can be found on the magazine website in the normal location, this month's issue page under **www.epemag.com/projects.html**

You can also take a look at my YouTube channel, where I run through the whole board layout process. Enter **http://goo.gl/6bzjov** or search YouTube for 'LPLC – Microchip Development Board'.

Next month

Next month, we wrap the series up by taking a closer look at surface-mount board layout, using the drum kit controller design, and then ship it out to a PCB manufacturer for the creation of a panel of boards.

Not all of Mike's technology tinkering and discussion makes it to print. You can follow the rest of it on Twitter at ***@MikeHibbett****, and from his blog at* ***mjhdesigns.com***

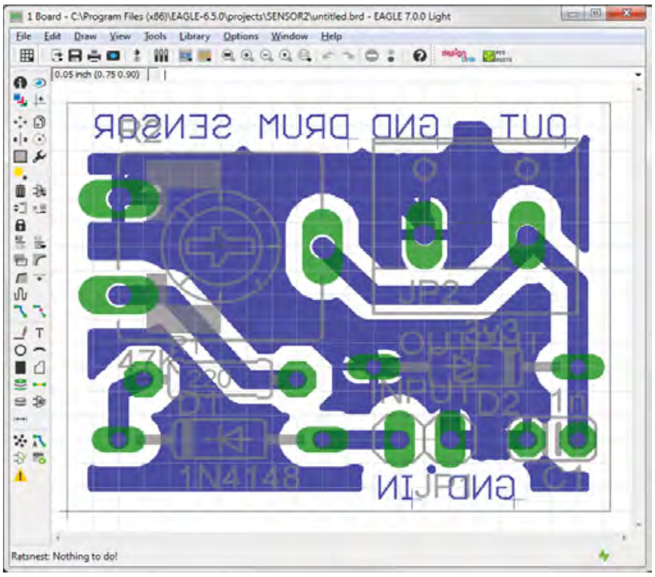


Fig.11. Completed board design

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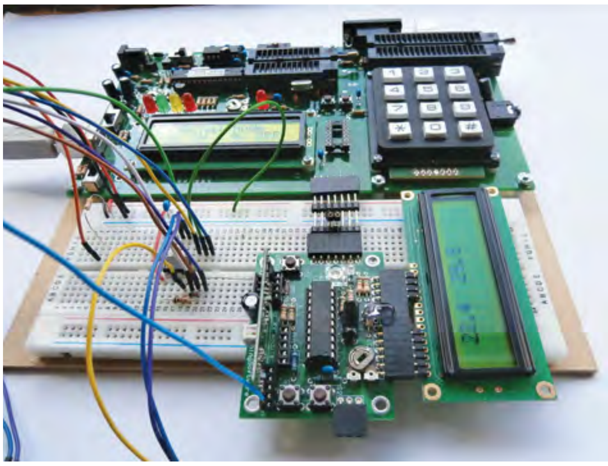
Bricks or Prefab? by Peter Brunning



Just after the war many thousands of new houses were needed immediately. The answer was the prefab which could be built by semi skilled workers in a fraction of the time normally taken. A brick layer can create unique buildings but all prefabs have a similar appearance. In this modern world of electronic control the prefabs are the ready built systems such as the Raspberry Pie and Arduino, and the bricks are the individual microcontrollers such as the Microchip PICs, and resistors, capacitors, etc. I believe that we should all start by leaning the fundamental skills to create simple microcontroller based control circuits and study low level programming. Even if you aspire to become a brain surgeon - seriously - the training in logical deduction would be invaluable.

Several times over the years I have been told by an experienced software engineer that “We do not do it that way any more”. But when asked if he did it that way the answer is always “Yes”. So good for his training but not good for your training! Yet he has become the expert! And that is my point. We all benefit from training in logical deduction and there is no easier way to get this experience than learning about the fundamental operation of a PIC microcontroller.

Customers who study with our course give very positive feedback. This is illustrated by an email which we received in October 2010 from South Africa - “Having taught for 15 years at Natal University, part of which involved Electronics, you might be interested in some feedback on how I have used your course...... If you want anyone to endorse your teaching method please feel free to ask me. I am most grateful for all your input.” Kind regards Robin.

And this email received in January 2014 from Australia - “I have been in the industry for 38 years so I did not buy the kit specifically for myself but for a friend who repairs controllers which are based on the PIC, so after looking at a few different kits, I settled for yours. I have found it to be well organised and easy to follow even a beginner would have no problems. Whilst I have done little programming with the new series of PICs your kit has inspired me to come up with some ideas.” Regards C.T.

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AUDIO OUT

By Jake Rothman

Test-bench amplifier – Part 1

It frequently surprises me how much homemade test equipment and assorted jigs audio boffins have – from capacitors stuck on the end of melted pen tubes to mattress-lined anechoic chambers. If you are rich enough, most specialist equipment can be bought ready-made, usually from lab suppliers at huge expense. However, it's never used frequently enough to justify the huge cost, so DIY design still dominates for most of us. Following my self-employed rule of getting multiple payoffs for development work, I'll be bringing to you my take on specialist circuits, starting with a test-bench amplifier.

Test-bench amps

This is one of the most common bits of equipment that audio developers build. Most people start off with a discarded Hi-Fi amp, but they have lots of disadvantages when it comes to the development bench.

1 They are too big
2 They emit excessive hum and EMI
3 They can't be turned on and off quickly and often make thumps and squeaks in the process
4 Inputs and outputs are at the back
5 Excessive features and knobs
6 Too powerful and noisy for small speakers used on the bench near to one's ears
7 Test equipment is often left on the whole working day. Most Hi-Fi amps have excessive quiescent power consumption generating unwanted heat
8 Hi-Fi amps often fail in test situations. An amp used on a test bench may end up having DC connected to its output and other accidental abuses
9 Hi-Fi amps use phono and mini jack connectors. For pro-audio, balanced XLRs are needed.

Basic design

So, let me introduce my take on the test-bench amplifier; the design has

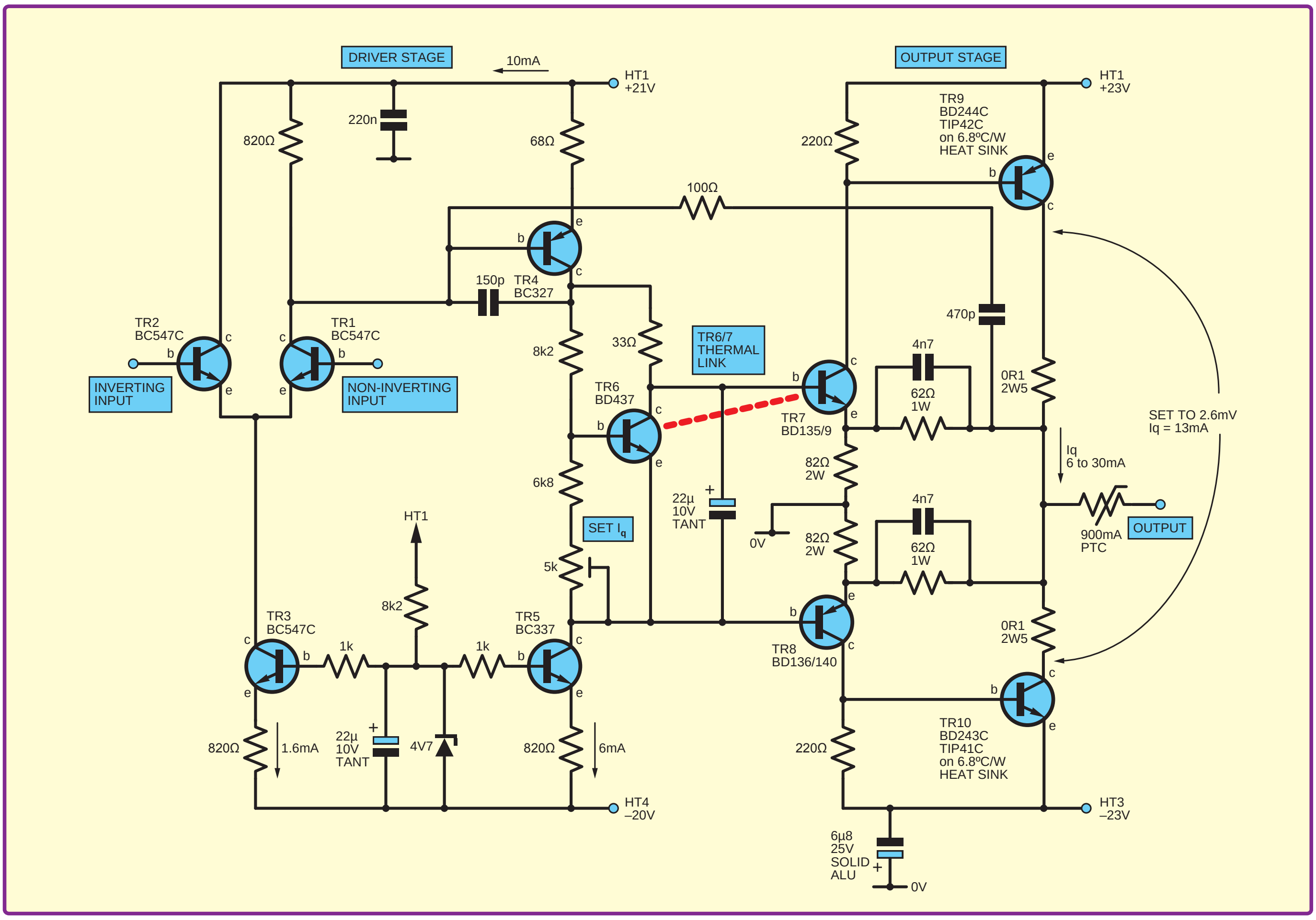


Fig.1. The basic guts of the amplifier – essentially a power op amp. Note TR3 and TR5 are current sinks, which could be replaced with current regulator diodes

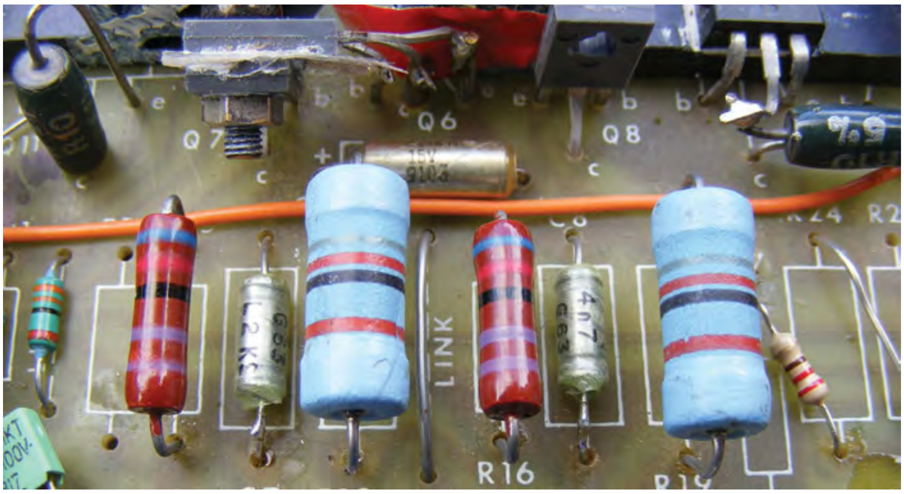


Fig.2. High-power resistors used in the feedback network on the CFP output stage

Fig.3. TR6 and TR7 are bolted together to obtain thermal stabilisation of I_q

evolved over the years, and doubtless will continue to be refined. It's a 20W RMS into 8Ω design based on a well-proven class-AB topology. A long-tailed pair (LTP) input stage, common-emitter voltage amplifying stage (VAS) and a complementary follower pair (CFP) output stage completes the line-up (see Fig.1). In theory, a standard monolithic power-amp chip, such as the LM1785 (see *Students' Amp* in *EPE* April 2007) would do the job almost as well. However, discrete circuits allow much more experimentation and optimisation. This amp has served as a circuit element development tool for many years. Also, if a blow-up does occur, then standard 'component drawer' transistors are used, Almost every European audio engineer has BC547Cs, BD139s and TIP41Cs, or their 2S equivalents. The circuit also builds on the capacitor ideas described in my previous columns.

Noise minimisation

Most chip amps are compensated to a minimum gain, and if gain is reduced below this figure then high frequency instability results. Most give an audible hiss and hum at close quarters. In this circuit the gain is around +9dB with the pot in the middle and +24dB full-up. With the speakers a foot away no noise is noticeable and measures around $2mV_{pk\text{-}pk}$. (In audio work noise is not allowed, fans are consigned to the WEE bin and I'm writing this on a Hush PC.)

Most amplifiers use unregulated simple diode/capacitor power supplies to ensure good peak current delivery from the output stage. Unfortunately, the input and driver stages need a low-noise supply, just like an op amp – since they are basically the same as the input stages of an op amp. Therefore, for minimum hum, the earlier stages must be separately decoupled. This is not normally done commercially, since it reduces the maximum output power where a normal emitter-follower output stage is used and looks bad on the spec sheet. It is rare for power-amp chips to have separate output stage and input/driver stage power pins.

Complementary feedback pair output

The complementary feedback pair (CFP) output stage needs a lower quiescent current (I_q) of 5 to 20mA for minimum crossover distortion compared to an emitter-follower design, which needs 30 to 100mA. This minimises power consumption when no output is being delivered, ensuring cool running. Also, the CFPs negative feedback factor can be reduced from 100% to give a small degree of voltage gain to compensate for rail voltage losses incurred in decoupling the driver stage. In this case, the voltage gain is 1.4 times, whereas an emitter follower is limited to just below unity. Using this system, transistors 1 to 5 could be replaced by an op amp. Output stage gain is not a good idea in big Hi-Fi amps using bipolar transistor outputs, since high-power feedback resistors are needed. Even this low-power circuit needs 2W resistors, as shown in Fig.2. The reduced feedback also increases distortion and the resistors limit the power into 4Ω loads. Note that in headphone amps and low-power designs like this one, such defects are not significant.

Another advantage of the CFP stage is that thermal compensation can simply be achieved by clamping one of the driver transistors to the V_{be} bias transistor, as shown in Fig.3. Additionally, the I_q is almost independent of the output transistor temperature. In emitter-follower output stages it is the output transistor temperature that needs to be tracked. By using a BD437 isolated-tab device for the bias transistor and separate heatsinks for the output transistors, fiddly mica washers and insulation bushes can be eliminated. The current-limiting effect of the feedback resistors helps to protect the amp from short-term shorts. For long-term overload protection, a positive temperature coefficient (PTC) Polyswitch resistor (see Fig.4) acts as a resettable fuse by going high in value if it gets hot. This is incorporated in the feedback loop, which nulls out its 0.24Ω resistance and reduces any distortion. PTCs have a long thermal time constant, which allows high current pulses to pass.

Shunt-feedback inverting configuration

This amp is inverting, which means there is no signal on either of the input transistors, giving lower distortion. In the normal non-inverting configuration, degeneration resistors are needed in the emitters of the LTP transistors. These resistors also reduce the open-loop gain. The penalty paid for using inverting mode is low input impedance, in this case 3.3kΩ.

Next month

In the Decemeber issue, we will continue examining the design of this flexible amplifier.

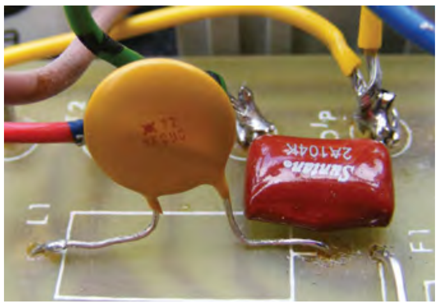


Fig.4. A Raychem Polyswitch is used as part of the design's output short-circuit protection

Voltage regulation – Part 2

LAST MONTH, we started looking at linear regulated DC power supplies in response to an *EPE Chat Zone* thread started by ***dave_g***. He posted a schematic of a 12V, 8A regulated power supply which suffered from stability problems. Later, ***james*** added another schematic for a supply with a similar specifications. Topics discussed included the value required for smoothing capacitors and the level of output voltage drop under high load currents. This month, we will look at the regulation process in more detail, including feedback and stability. Other issues that have been raised include the use of an integrator in the feedback loop (in ***james's*** circuit) and how this affects circuit performance – we will also address this.

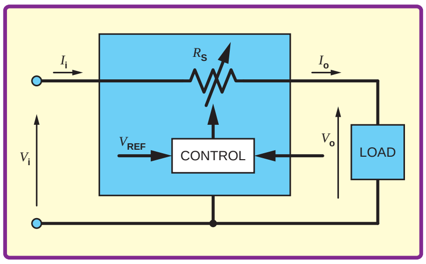


Fig.1. Series regulator concept

Last month, we introduced the concept of a regulator as a feedback control circuit, as shown in Fig.1. The regulator compares its output voltage (V_o) with a reference voltage (V_{ref}) and adjusts a 'series element' (R_S in Fig.1) so that V_o maintains a fixed relationship to V_{ref}. Conceptually, the value of R_S is changed so that the voltage dropped across it (I_oR_s) is such that it produces a constant V_o as V_i and I_o vary (note $V_o = V_i - I_oR_s$). The regulator's control system is not perfect, so variations in V_i and I_o will cause some variation in V_o, which is characterised as line regulation and load regulation respectively. We discussed these parameters in detail last month.

Voltage dropout

In order for the regulator to work at all, V_i must be greater than V_o by a certain amount, known as the 'dropout voltage'. The dropout voltage is dependent on how the series element is implemented – it will be a transistor circuit (the 'pass transistor'), but may use single or multiple transistors and either bipolar or MOS technology. There are significant differences between different implementations. A small dropout voltage is desirable because it reduces the amount of power dissipated by the regulator – as we saw last month, the efficiency of a regulator is directly related to the ratio of V_o to V_i. The term 'low dropout' (LDO) is used to describe regulators with this property and many modern regulator chips use LDO architectures.

LDO regulators are needed in applications where the voltage drop across the regulator must be as small as possible to accommodate voltage constrains and to minimise dissipation and maximise efficiency; typically this is the case in battery-powered systems. Early linear regulators, such as the 7805 and LM340 suffered from relatively high power dissipation due the large voltage drop (typically a couple of volts) from input to output of the regulator. LDO regulators typically have dropout voltages of less than 500mV, and low as 20mV for low-current loads. Switching regulators can also achieve high efficiency but produce more power-line noise than linear regulators. Hence, LDO regulators are used in systems requiring low-noise power supplies. In battery-powered systems the regulator's quiescent current (current taken when there is no load) is also important. Low quiescent current also improves efficiency.

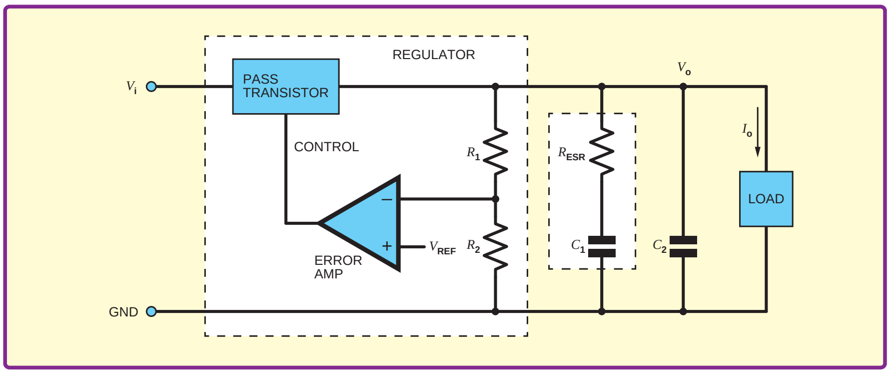


Fig.2. Typical linear regulator circuit

Fig.2 shows a more detailed, but still simplified schematic of a typical linear regulator. This circuit structure applies to both LDO and non-LDO regulators, with the key difference being in the pass transistor circuit. The regulator contains a potential divider (R_1 and R_2) that produces a fixed fraction of the regulated supply voltage. This is compared with the fixed reference voltage. If the regulator output voltage decreases then the error amplifier's output will increase because the potential divider is connected to its inverting input. Thus, the increased output voltage will increase the control signal to the pass transistor, and hence the current to the load. This will tend to increase the regulator's output voltage, offsetting the initial decrease. This negative feedback loop will keep the potential divider voltage equal to the reference voltage and hence keep the output voltage fixed as the load varies. However, as with any negative feedback loop, there is the possibility of instability, depending on the frequency response of the loop.

Pass transistor technology

The NPN 'pass transistor' circuit used in a standard regulator is shown in Fig.3. This circuit requires a minimum of two V_{BE} and one $V_{CE.SAT}$ voltage drop across it, accounting for this

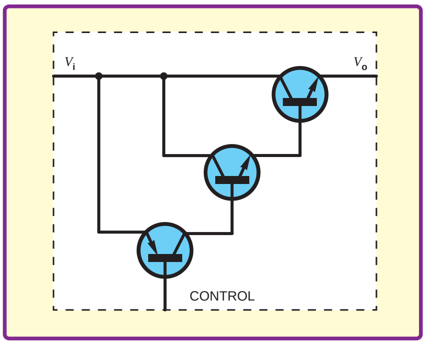


Fig.3. Typical pass transistor circuit for a standard regulator

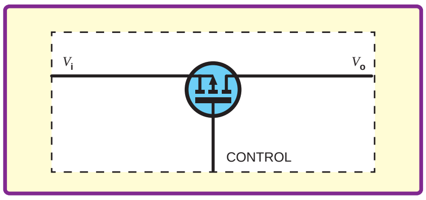


Fig.4. Single PMOS pass transistor for a LDO regulator

type of regulator's typical dropout voltage in the range 1.5V to 2.5V. LDO regulators use a single transistor, which may be bipolar or a MOSFET. The circuits posted by ***dave_g*** and ***james*** in the *Chat Zone* discussion both (effectively) use a single PMOS power transistor as the pass transistor, as shown in Fig.4 (although ***dave_g*** uses multiple devices in parallel).

Time response

The output of a circuit does not respond infinitely quickly to changes at its input, so any signal fed back from the output to the input will be offset in time with respect to the original input. Consider a simple case in which there is a fixed delay from input to output of the (feedback control) circuit whatever the input signal does (things are usually more complicated than this). Say, for example, this delay was 0.1µs. If the input frequency was 100Hz this time would be 0.001% of the signal's cycle time and could probably be considered insignificant. However, at 2.5MHz the 0.1µs delay is a quarter of the signal's cycle time of 0.4µs. This would usually be expressed by saying that the circuit had a phase shift of 90° at 2.5MHz (one complete cycle of the waveform is 360°). At 5MHz, 0.1µs is half the cycle time of signal. This is a significant point because a phase shift of 180° is equivalent to multiplying the signal by –1.

Phase shift and stability

Consider the total phase shift round the circuit's feedback loop as we increase the signal frequency. In the case of the regulator (Fig.2) this is the path from the output via the potential divider, then the error amplifier, then the pass transistor and so back to the regulator's output. Once the phase shift along this path reaches 180° we have effectively inverted our feedback signal – what was negative feedback has become positive feedback. Positive feedback is what you need to make an oscillator, so our circuit may become unstable. For this instability to occur the gain around the feedback loop must be greater than one at the frequency at which the phase shift reaches 180°.

Generally, the gain of a circuit such as an amplifier will decrease, and the phase shift will increase, as frequency increases. The question is – will the above conditions for instability occur as frequency increases? We can measure how close a circuit is to being unstable

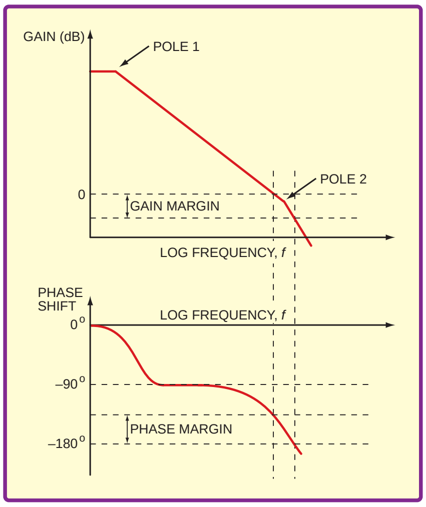


Fig.5. Variation of gain and phase shift around a feedback loop with signal frequency, illustrating gain margin and phase margin

using the concept of gain margin and phase margin. First, as gain around the loop approaches 1 the phase shift must be less than 180°. The difference between the phase shift at this point and 180° is the 'phase margin'. Second, as the phase shift around the loop approaches ±180° the magnitude of the gain must be less than 1. This difference can be expressed as the 'gain margin' (usually in dB).

Gain margin and phase margin are illustrated in Fig.5, which shows a simple frequency response curve. Note that a gain of 1 is 0dB and that phase shift is negative because the output lags behind the input signal in time. The shape of the frequency response curve of a regulator is usually more complex than the one shown in Fig.5, but the concepts of gain margin and phase margin apply in the same way. We will discuss various other aspects of frequency response curves in more detail a little later.

Frequency response

What determines the frequency response of a regulator's control loop? The basic answer is the presence of frequency-dependent components, specifically capacitance or inductance, although here we will only be concerned with capacitance. This capacitance may be due to capacitors designed into the circuit, or due to the capacitance of other components (eg, a MOSFET gate) or the wiring. Capacitance that is not deliberately designed in is often referred to as 'parasitic capacitance'. Similarly, the circuit will contain designed-in resistors but there will also be the drain-source resistance of the MOSFET, the error amplifier output resistance and the wiring resistance to consider.

Although we can consider the frequency dependence of a capacitor on its own – as frequency increases its effective resistance decreases – capacitance in circuits such as the

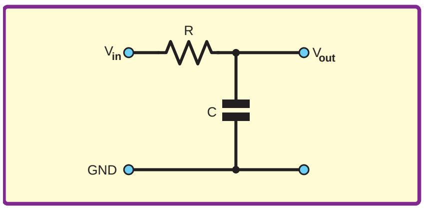


Fig.6. RC circuit

regulator occurs in conjunction with resistors to form RC circuits, such as the one shown in Fig.6. This circuit acts as a potential divider, so V_{out} is a fraction of V_{in}. As frequency increases, the value of R does not change, but the effective 'resistance' of C decreases. This means that as frequency increases, with V_{in} at constant amplitude, V_{out} will decrease.

If we plot the frequency response of the circuit in Fig.1 it can be approximated to that shown in Fig.7, which (like Fig.5) uses straight lines, although the actual response is a smooth curve. The gain (ratio of V_{out} to V_{in} expressed in logarithmic form in decibels) is almost constant at very low frequencies (the gain will be negative in this case because this circuit attenuates). At very high frequencies the gain decreases at a constant rate of 20dB per tenfold increase ('decade') in frequency. (Note that the frequency is also plotted on a logarithmic axis.) The breakpoint between these two points, where the two approximating straight lines on Fig.7 meet, is called a 'pole' and in this case is at a frequency given by $f_p = 1/2\pi RC$.

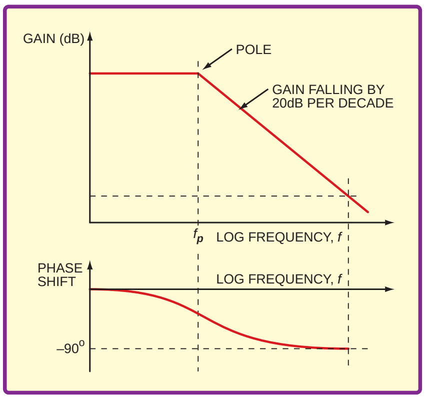


Fig.7. Frequency response due to a single pole

Poles and zeros

The term pole comes from more advanced analysis of frequency-dependent circuits. Here, two-dimensional 'complex numbers' are used to represent signals and circuit characteristics in a mathematically system referred to as the Laplace domain. In this representation the circuit response rises to infinity at the 'breakpoint' frequency just discussed and hence looks like a pole on a two-dimensional graphical plot. Gain will decrease at a rate of 20dB per decade *more* above a pole's frequency compared to below it.

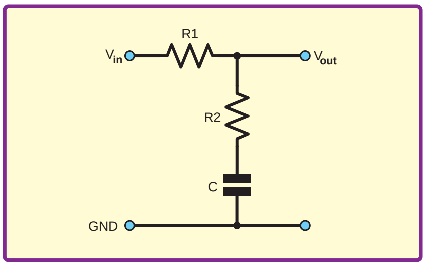


Fig.8. This circuit has a pole and a zero

There is another type of breakpoint, which can occur in frequency responses. This is called a zero (again this is descriptive of the response in the Laplace domain). Gain will decrease at a rate of 20dB per decade *less* above a zero frequency compared to below it. The circuit in Fig.6 has one just pole, but other circuits will have more complex responses. For example, the circuit in Fig.8 has one pole and one zero.

A pole produces a phase shift of +90° at frequencies sufficiently beyond the pole frequency. Similarly, a zero produces a –90° phase shift. When designing feedback circuits, additional poles and zeros can be added to manipulate the overall frequency response to achieve a more stable design. A pole and a zero at more or less the same frequency tend to cancel one another out.

Real-world examples

A typical frequency response for an LDO regulator IC is shown in Fig.9. We can think of the RC circuits as embedded within the regulator (or other circuits) in order to gain an understanding of the frequency response. If we can identify all the poles and zeros we can work out the response and determine if the circuit is stable. For example, an RC circuit like that shown in Fig.6 occurs where the output of the error amplifier is connected to the pass transistor (in Fig.2). R is formed from the error amplifier's output resistance, plus the wiring resistance and C is formed from the pass transistor's input capacitance (eg, MOSFET gate capacitance) plus the wiring capacitance. This will cause a single pole in the regulator's frequency response (pole 2 in Fig.9).

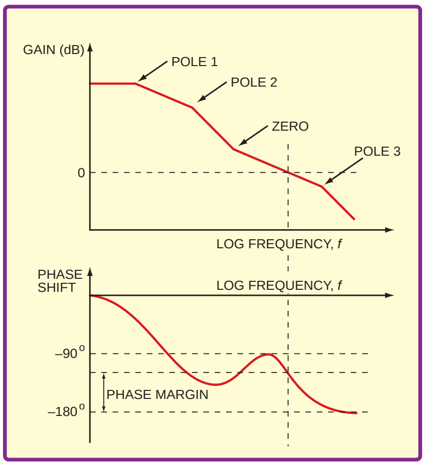


Fig.9. Typical frequency response of a compensated LDO regulator

The importance of correct capacitor selection

The capacitor connected to the regulator's output (C_1 in Fig.2), its internal resistance (R_{ESR}, where ESR is the equivalent series resistance) and the drain-source resistance of the pass transistor (not shown explicitly in Fig.2) form a circuit like that in Fig.8. This adds a pole and a zero to the regulator's frequency response (pole 1 and the zero in Fig.9). The MOSFET resistance is not constant with, so the frequency response will vary with load current. In a typical LDO regulator circuit, C_1 will be a solid tantalum capacitor with a value of 5µF to 10µF with an ESR of 0.01Ω to 10Ω. This is important for regulator stability because the zero reduces the amount of phase shift as frequency increases around the zero frequency (thus increasing phase margin).

The value of C_1's ESR can make the difference between a stable and unstable regulator. If the ESR is too low then the zero frequency will be above the unity-gain frequency and will not help stability. If the ESR is too high, the zero frequency is too low, allowing the overall loop bandwidth to get sufficiently wide to cause stability problems. Datasheets for LDO regulator ICs are very specific about what type of capacitor to use. If the ESR value is not within a given range (either too high or too low) the zero will not be at a suitable frequency and the circuit will not be stable.

Capacitor C_2 in Fig.2 represents the bypass capacitors that are placed close to ICs in a typical electronic circuit (usually ceramic types). These typically each have a value of 0.1µF and very low ESR. Their total value will be much lower than C_1. Hence, C_2 together with the output resistance of the MOSFET, form another pole in the response (pole 3 in Fig.9). This pole is typically at a high frequency (above the unity-gain bandwidth) and does not affect the stability – however, in some situations, adding low-ESR bypass capacitance may cause stability problems.

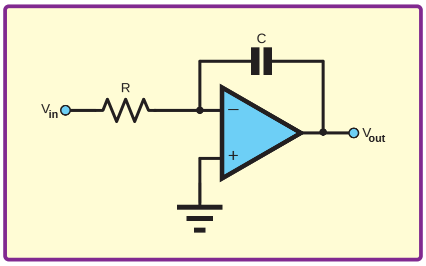


Fig.10. Op amp integrator

The preceding discussion gives some idea of the issues and complexities associated with regulator stability. For a circuit built with discrete components, such as those posted in the *Chat Zone* it may be very difficult to determine all the relevant values (eg, wiring parasitics) to facilitate any form of calculation. However, and just as important as design applications, an understanding of the concepts relating to regulator stability may help when diagnosing problems.

Integrator action

The circuit posted by ***james*** uses an integrator as part of the error amplifier circuit. An integrator circuit is shown in Fig.10. In the ideal case, this circuit has infinite

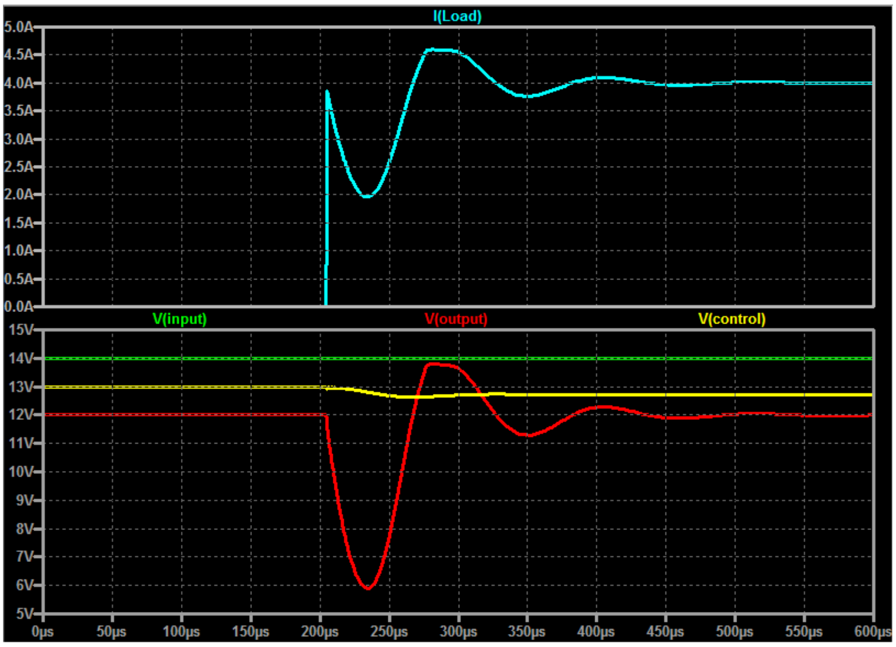


Fig.11. Illustrative transient response for regulator (slower integrator in loop – compare with Fig.12)

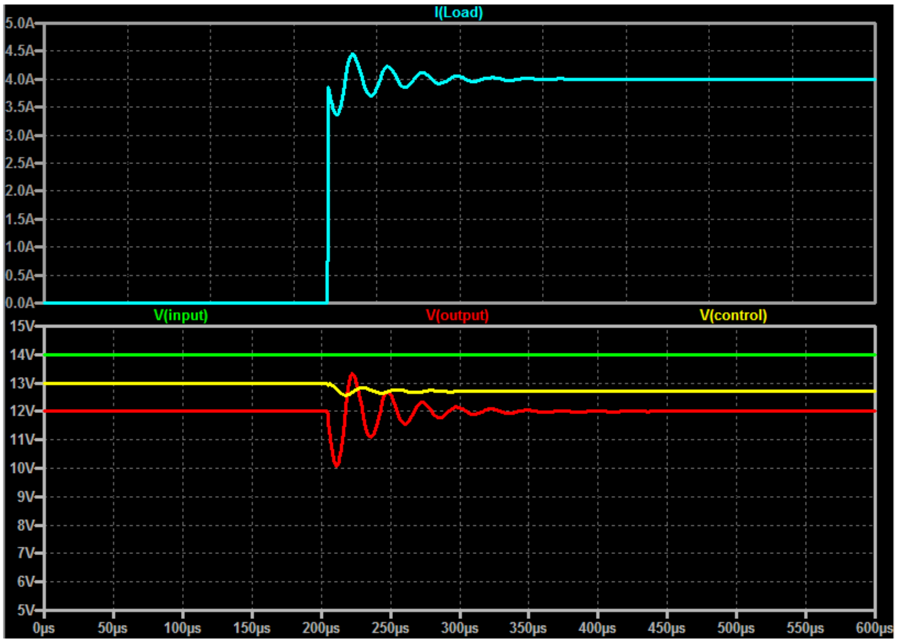


Fig.12. Illustrative transient response for regulator (faster integrator in loop – compare with Fig.11)

gain at DC and the gain falls steadily with increasing frequency, reaching a value of 1 (0dB) at a frequency of $1/2\pi RC$ (above these frequencies the integrator attenuates). The circuit in Fig.10 cannot be used on its own because any offsets or bias currents will cause the capacitor to charge until the op amp saturates. These are DC signals, so looked at another way, the infinite gain at DC implies the op amp must saturate unless the DC input is exactly zero (no offsets). Despite these issues, an integrator can be used within a feedback loop where the feedback stabilises the DC conditions, preventing saturation.

A circuit like that in Fig.10 is used in standard (non-LDO) regulators to provide stability. The use of a pass transistor circuit, such as in Fig.3 (which has different properties to the PMOS circuit) means that there are no low-frequency poles inherent in the circuit. Adding a feedback capacitor to the error amplifier introduces a low-frequency pole, which causes the gain to fall below one before any of the other (higher frequency) poles can cause the phase shift to reach 180°. This technique is called dominant pole compensation. In IC LDOs this approach cannot be used due to low-frequency pole 1 (Fig.9).

The discrete designs discussed in the *Chat Zone* use a PMOS pass transistor, but the characteristics of the components may be significantly different from those in a typical LDO IC, so although the 'same' poles will be present their relative frequencies may be different.

Changing the capacitance value in an integrator, on any other change to the regulator's feedback circuit does not only change its degree of susceptibility to instability, but also its transient response. This is illustrated in figures 11 and 12. The signals plotted correspond to the Io (I(load)), Vi (V(input)), Vo (V(output)), and control (V(control)) signals in Fig.2. These graphs show what happens when a sudden increase in current demand occurs (in this case a fast rise from zero current demand to 4 A). Figs.11 and 12 shows the situation for a regulator circuit similar to the once posted by ***james***, with different integrator time constants (values of C in figure 10), and illustrate how varying the control loop frequency response also affects the time response (the effect of changing this capacitor was queried in the Chat Zone thread). In both cases the control signal can be seen adjusting to a new value to achieve the regulation.

The regulator Fig.11 has a lager integrator time constant (larger C value), is slower to settle, and has larger voltage excursions. These are factors which are important for loads such as high speed digital circuits, where a poor transient response from the regulator may cause serious problems. For other types of load the transient response may be much less important.

Finishing off!

THERE is an old saying, 'you should not judge a book by its cover', but I would guess that most people tend to do just that. In the current context, it means that it does not matter how much skill and effort goes into the electronics within, or how neat the interior looks, it is the exterior of a project that your efforts will be judged by. Ignoring that and being entirely practical about matters, a well-finished gadget with neat labels is likely to be easier to use, especially if it will be used by others and not just yourself.

The rub

In the past there were various non-computerised methods for producing neat labels or even complete front panel overlays. Most of these low-tech methods are now obsolete, and even the ever popular rub-on lettering seems to be difficult to obtain. Due to a lack of the necessary materials, life is difficult for anyone wishing to use traditional methods of label and panel production. To a large extent this change is due to the abandonment of rub-on lettering and the like in the commercial world. In that world, where 'time is money', the advantages of high-tech methods produced a steady decline in the demand for traditional tools and materials.

It would be an exaggeration to say that none of the old methods are usable any more, but some, such as the simple photographic techniques for producing high quality panel overlays are long gone. Most of the others are still possible, but are much more limited in scope. You can still obtain dry transfer lettering, but in a much reduced range of fonts and sizes.

If you do not have access to a computer equipped with some sort of printer, it would probably not be economically viable to buy the necessary equipment just for making the occasional front panel overlay or set of labels. However, as most people already own suitable equipment, this would probably be their preferred method of doing things. Anyway, in this article only the computerised approach will be considered. Turning computer designs into actual labels and overlays will be considered in the next article, as will rub-on lettering and other non-computerised methods.

Word perfect

In order to produce a few panel legends you do not really need any sophisticated design or drawing software. Something beyond a simple text editing program is required, but even the most basic of word-processors should be able to produce lettering in a range of fonts, colours, styles and sizes. In a standard Windows installation the WordPad program is included in the Accessories group of programs, and this is really all that is needed. One slight problem with WordPad is that it provides no easy means of changing the background colour. This is fine if you are happy with a white, or a totally clear background when printing onto a transparent medium.

Of course, coloured paper can be used, which is fine when using black lettering, but it produces a colour shift with lettering of any other colour. It is actually possible to change the WordPad background colour, which is simply the default Windows window colour. It is just a matter of using the normal Windows control facilities to temporarily change this to the required setting. However, for easy control of the background colour it would be better to install one of the free word-processors that are available, such as the one in the Open Office suite.

The range of fonts available when using application software is generally only limited by the number of them actually installed on the computer. However, there are plenty of additional fonts available on the Internet for little or nothing. The default set of fonts installed on a PC is wide-ranging, and covers everything from the most staid of designs to the outright zany. There should be something suitable for any project.

Programs tend to use point sizes for text, rather than the height in millimetres. There are 72 points to one inch, so one point equals about 0.353 millimetres. Dividing the required height by 0.353 therefore gives the equivalent point size. This works out at about 8.5 points for 3mm high lettering and 14 points for 5mm high text. An advantage of the computerised approach is that you can print the labels on a single sheet in a range of sizes, and then select the one that looks the most suitable when you see the labels 'in the flesh'.

Graphic illustration

In order to produce labels with really elaborate lettering, or complete front panel overlays, it is necessary to have some form of graphics software. Although paint and photo-editing programs can be used in this application, they are not primarily aimed at this type of thing, and they tend to be more awkward to use than the alternatives. What you want are CAD (computer-aided design) and illustration programs. CAD programs are primarily intended for technical drawings such as circuit diagrams,

scale drawings of machine parts, and house plans. The ability to produce designs accurately to scale is important when producing panel overlays, and CAD programs can easily handle anything of this type. They usually have facilities for adding text in various fonts, styles, sizes and colours, but will probably not offer much more than that.

Most professionals probably use illustration software when producing panel designs for commercial equipment. Using an illustration program it is possible to draw accurately to scale, but there is also great scope for 'doing your own thing'. There are facilities to fill shapes with complex patterns and graduated colours, and it is often possible to apply these to text as well. There are tools for distorting objects and drawing freehand. Illustration software enables designers to take a freer approach, but precision is still available when it is needed.

A potential problem with illustration software is that it is easy to get carried away with things and end up with a sophisticated design that uses various special effects, but looks totally out of place on the finished unit. There is nothing wrong with using clever or zany effects, and they can work very well in the right context. However, they need to be reserved for the right types of project, and are likely to look out of place on more sober projects, such as items of test equipment. A panel design should be matched to its project. Front panel designs should be imaginative and attractive, but things should not be taken to the point where they become confusing rather than helpful.

Free for all

The main problem with CAD and illustration software is that it is produced very much with professional users in mind, and it is priced accordingly. This type of software can easily cost more than the hardware used to run it. Buying software of either type to produce the occasional front panel design is not a practical proposition for most people. Fortunately, there are some good low-cost and free alternatives available. The full range of features available from expensive illustration or CAD software might not be available, but the best free graphics programs are more than adequate for producing good quality front panel designs. This type of software is quite complex and learning to fully exploit it can be very time consuming, but it should not take long to learn the basics. An in-depth knowledge of the software is not needed in order to make a start with panel designs.

After coming close to extinction, free drawing software has undergone something of a revival in recent years. A search of the Internet should locate several useful CAD and illustration programs that are available as free downloads. Much of this software is primarily aimed at 3D modelling, and while this type of software might be usable in the current context, it is not ideally suited to it. A number of sophisticated CAD programs are available as free downloads, but free illustration software is 'a bit thin on the ground'. It does exist though.

Inkscape is an open source illustration program, and Serif DrawPlus SE is an illustration program from the British company Serif Ltd. These have both been featured before in this series, and they probably remain the best two options if you require free software of this type. Inkscape is the more sophisticated of the two programs, but DrawPlus SE is easier to learn and use, and it has all the features needed for producing front panel designs. It is available as a free download from **www.freeserifsoftware.com** and not the main Serif site (**www.serif.com**). It is necessary to register the DrawPlus SE in order to use it for more than 30 days, but registration is not needed for Inkscape. Since both programs are free, it costs nothing to try them both.

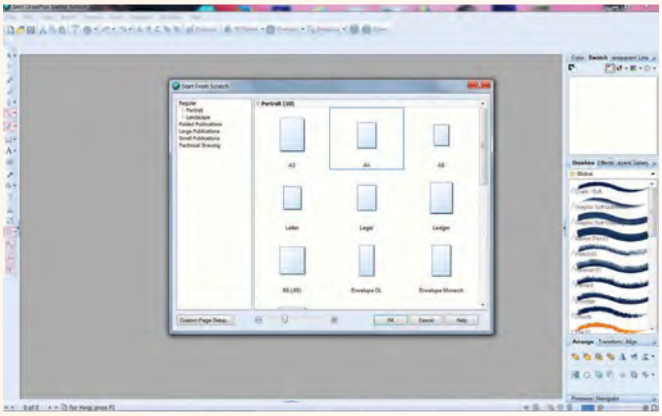


Fig.1. DrawPlus has a conventional screen layout for a graphics program. The first step is to select the paper size

Right toolbars for the job

Fig.1 shows DrawPlus when it is initially launched, and the first task is to select the page size. This would normally be the paper size that will be used when printing designs. The screen layout is the conventional one for a graphics program, with a menu system at the top, and various drawing tools available from the toolbar down the left-hand edge of the screen. Some of the more advanced features are not available on the free version of DrawPlus, but the main ones such as lines, shapes, fills, and brushes are all available.

There is a toolbar below the menu bar, and this provides editing facilities such Save, Undo, and Redo. Another bar beneath this provides facilities that depend on the tool selected at the time. With the Text tool selected, for example, there are controls for the usual text options such as size, font, style, and justification. There is a large panel down the right-hand side of the screen that is used for such things as selecting colours and brushes. This can be resized or hidden completely when it is not needed. Some buttons along the bottom of the screen on the right give quick access to frequently used facilities such panning and zooming. The large central part of the screen is the drawing area.

The normal starting point is to draw the outline of the front panel using the rectangular shape tool, after which the holes are added in the appropriate places. Accurate drawing is aided by the horizontal and vertical rulers above and to the left of the drawing area, and an optional grid can be brought up on the screen. Another option is a Snap facility that constrains objects so that they can only be drawn on the grid. An Align facility can be used to straighten things if a row of holes should ends up looking a bit 'higgledy-piggledy'.

There are two colours associated with most objects, which are the stroke (outline) and a fill colour. The stroke width is adjustable, and in the current context it would normally be set quite thin, together with black as the stroke colour. The panel on the right-hand side of the screen gives quick access to a wide range of colours, and also to dialogue boxes that permit fancy fills, such as patterned and graduated ones. It is possible to effectively get rid of outlines by setting a width of zero, and fills can be removed by using the 'None' option.

Elements of the design can seem to disappear when using anything other than transparent or empty fills. What is actually happening is that one object is notionally behind another one, and is blocked from view by it. Sometimes layers are used to control the order in which elements are stacked, and (or) there could be an Arrange menu that enables objects to be selected and moved backward or forward. This is something that needs to be mastered early in the proceedings if complex designs are to be produced.

Fig.2 shows an example design produced using DrawPlus. The panel has been given a complex graduated fill, as has the large text, which is also in a fancy font. The labels for the controls are in a simple font, but the word 'Frequency' has been fitted to a path. In this example, the path is an arc, but the arc itself is not visible and it just acts as a guide for the text. When producing hard copy on some types of transparent media it is necessary to print a mirror image of the design, because it will be printed onto what will be the rear side of the overlay. The reversal process can often be handled by the printer driver, but if necessary the 'flip' or 'mirror' facility of the graphics software can be used. In Fig.1 I have copied the entire design and used the Flip facility to reverse the copied version.

CAD

A number of powerful CAD programs are available as free downloads, but some are a bit dated and not compatible with modern operating systems. Some others are specialised or not well suited to the current application for other reasons. The free versions of DraftSight (**www.3ds.com**) and DoubleCAD (**www.doublecad.com**) are both worth investigating. These both require registration in order to use the free versions.

DraftSight has what has now become the standard user interface for CAD programs (Fig.3). The top part of the screen is similar to that of DrawPlus, and there is also a toolbar with buttons for the drawing tools down the left-hand side of the screen. The toolbar on the opposite edge of the screen provides quick access to editing tools such as deletion, scaling and rotation. The bottom section of the screen provides hint text and other information from the program. There is also a command line here, where parameters and instructions can be entered. The panel on the right is a properties window that can be used to edit the main parameters of any selected objects. This window can be repositioned, resized, or switch off altogether.

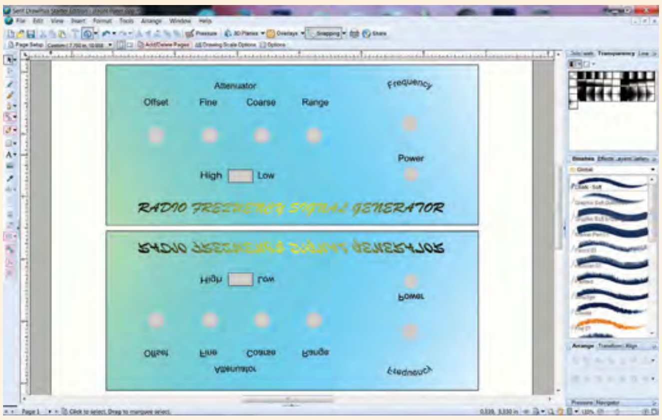


Fig.2. Normal and 'flipped' versions of a front panel design made using DrawPlus. This uses graduated fills and text fitted to a path

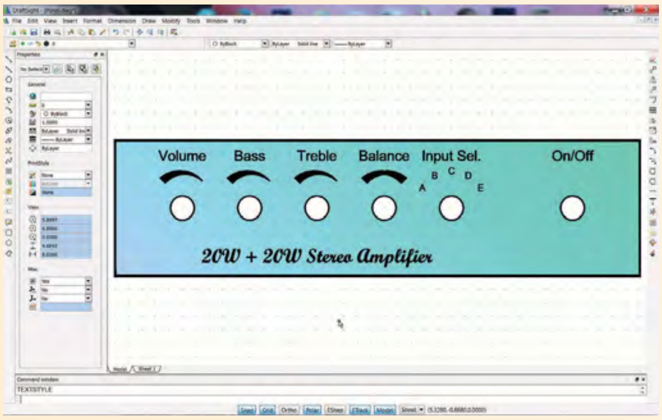


Fig.3. DraftSight has a conventional CAD interface. In terms of special effects it is more limited than an illustration program, but it can still provide good results

There is a free DraftSight instruction manual in PDF format that can be downloaded, and this makes it easy to get started with the program. Fig.3 shows a front panel design that demonstrates some of the available features, such as different sizes of text, a fancy font, a graduated fill, and varying widths within a line. Using a CAD program it is relatively easy to produce dials and scales, but some of the fancy effects of an illustration program are lacking.

DoubleCAD is a modern version of TurboCAD, which is a program I used back in the early days of PCs! It has the option of using the old TurboCAD user interface, or a modern type that is similar to that of DraftSight and some other current CAD programs. Fig.4 shows the program with the modern user interface selected. CAD programs are ideal for circuit diagrams or any other drawings associated with electronic projects. Both DoubleCAD and DraftSight have the ability to load drawings in AutoCAD dwg and dxf formats. The circuit shown in Fig.4 is dwg file for an *EPE* project from many years ago, and it loaded into DoubleCAD without any difficulty.

Safe downloading

There are many free programs on the Internet that are of use to those with an interest in electronics, including such things as complex PCB design programs and circuit simulators. It is well worth investigating this software, but when downloading any free programs it is important to proceed with caution. In order to avoid downloading programs with adware and various types of malware added it is best to do some research, and only download programs that are well known and trouble free. It is also advisable to only download from the official site for a program, or via links provided on that site.

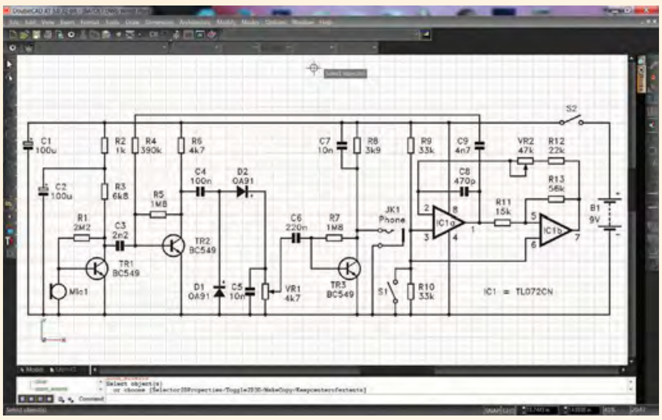
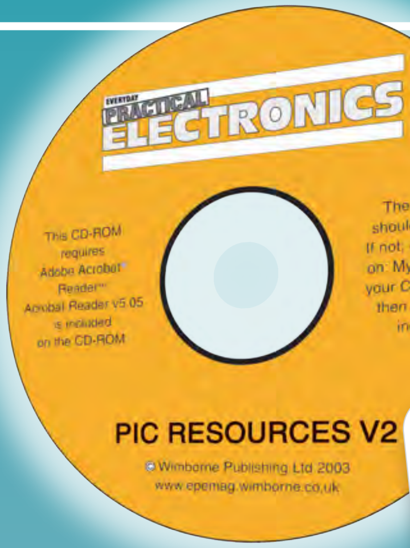


Fig.4. DoubleCAD with the 'modern' user interface selected. Here a dwg format circuit diagram produced using another program has load without problems

EPE PIC RESOURCES CD-ROM V2



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The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

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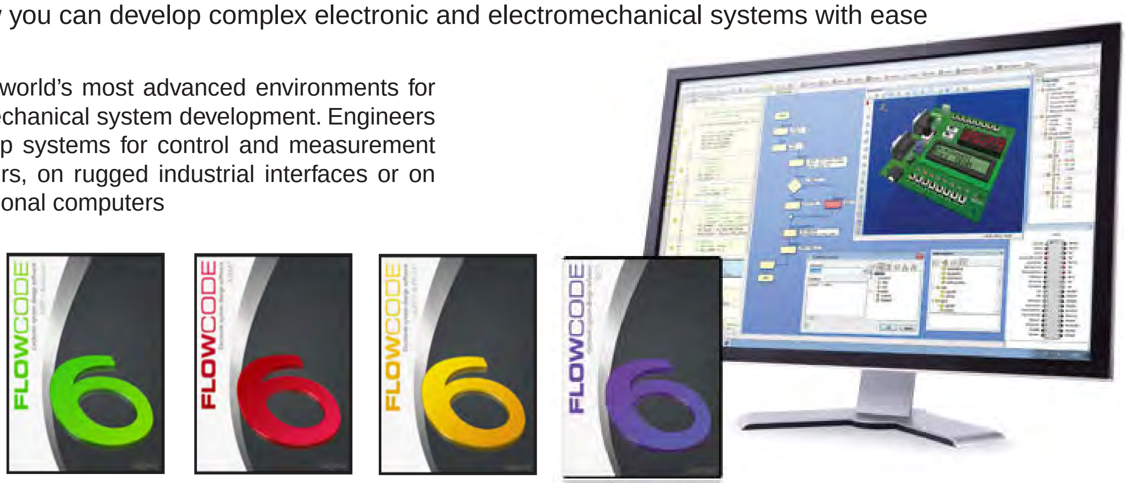

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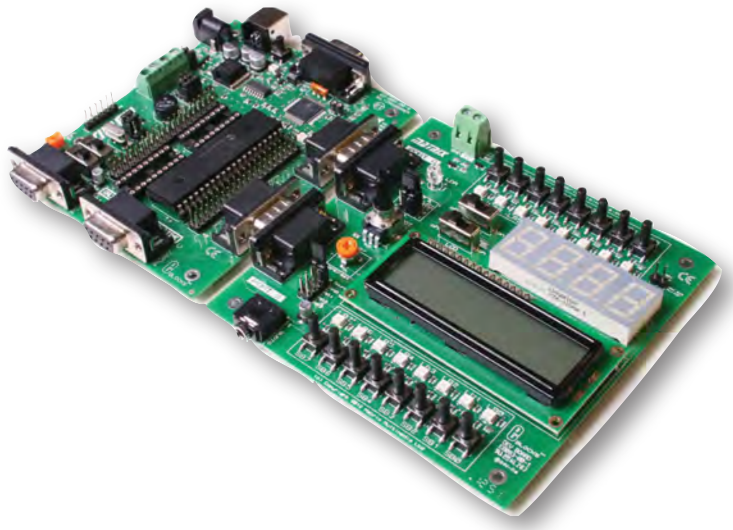

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SOFTWARE

ASSEMBLY FOR PICmicro V5

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

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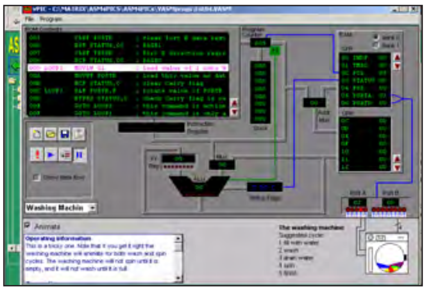

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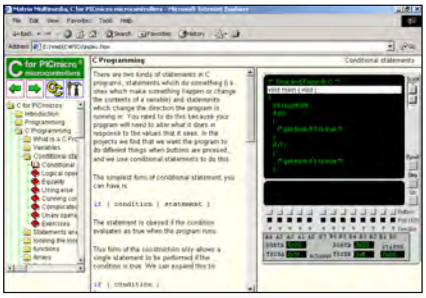

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6 (see opposite page)

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

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- Allows complex PICmicro applications to be designed quickly
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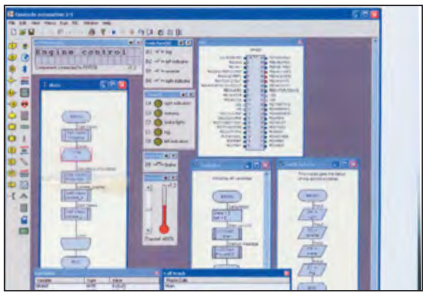
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Features include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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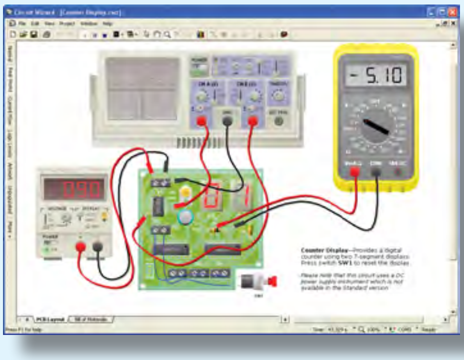

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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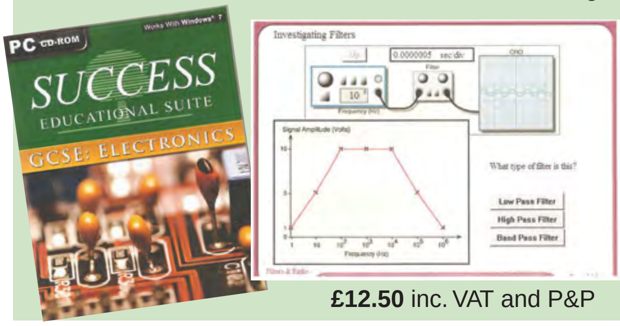

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Max's Cool Beans

By Max The Magnificent

A shocking experience!

Why is it that we tend to become somewhat blasé about things as we get older? Take electrostatic discharge (ESD), for example. When I was a younger man, I was very aware of ESD and I always took appropriate precautions. As the years passed, however, I became a little more relaxed about things. It's easy to follow an ESD regime if you are working in a lab with antistatic mats and wristbands lying around all over the place – it's a tad more tiresome when you're working at home on the kitchen table.

Having said this, it's even more tiresome when you keep on blowing things up, like your tri-colored LEDs or input/output pins on your microcontroller board. Yes, of course I'm speaking from experience (he said through gritted teeth). Recently, after a couple of unfortunate incidents, I decided that enough was enough and I needed to get a grip on myself.

I started by investing in a couple of electrostatic wristbands and a large electrostatic mat. Both of these have an expandable cable attached. Somewhere in each cable is a 1MΩ resistor. On the end of each cable is a crocodile clip (or alligator clip if you prefer). You can use this clip to connect your mat or band to a ground point. Alternatively, if you pull the clip off, you reveal a banana plug.

The banana plugs work well in a lab where you have official grounding points all over the place; the crocodile clips tend to be more of a pain – what do you clip them to? In reality, you've got two main choices. The best solution is to connect everything (eg, you, your components, your circuit boards, your work-surface) to an electrical ground (third wire). The reason this is the preferred solution is that your other equipment (soldering iron, 'scope, waveform generator) will also be connected to the electrical ground. The alternative is to use equipotential bonding, which simply means that all of the conductors and dissipative materials in the environment are connected together and are therefore at the same potential.

I started by attaching my crocodile clips to a power supply case, but sometimes that is not plugged in. Next, I plugged a flying lead into my breadboard and attached my crocodile clips to it, but this was less than ideal because the flying lead kept on popping out… or I jerked the breadboard… or things got tangled up. Eventually, someone recommended a 'ground plug adaptor from banana jack to standard outlet' (**http://bit.ly/1nXPN0B**). This link is for a US plug, but I'm sure there are equivalents in your area. On the one hand, these are mega-expensive at $7 for a gizmo that can cost only a few cents to produce; on the other hand, they are a one-time buy that will last me the rest of my life. I now have a power strip on the table in front of me, the other end of which is plugged into a wall socket, and I have four of these adaptors plugged into it so that I and any companions can all be ESD-free.

This is just a small portion of my local Hamfest in Huntsville, Alabama

A festive time

I can't believe it's been a year since I first went to the Huntsville Hamfest (**http://bit.ly/1t1dR5O**). That was where I purchased a 4 × 4 × 4 tri-colored 3D LED cube kit, which kicked-off my adventures with the Arduino. Time certainly does go quickly when you're having fun, and going to this type of electronic flea market really is lots of fun, which is why I found myself there again this year.

A lot of my current electronics projects feature the use of antique analogue meters; their black Bakelite surrounds look very stylish when mounted on brass panels. Thus, my goal when visiting the Hamfest this year was to pick up a bunch of these meters. What can I say? I was spoiled for choice. There were at least three stalls that boasted boxes and boxes of these little rascals. I remember that I used to purchase them individually for exorbitant amounts from eBay – but they can be as cheap as $2 apiece at a Hamfest.

I'm afraid I did become a little over-enthusiastic. I made several trips back to squirrel things away in my truck, and I didn't realise quite how many items I'd purchased until I returned home and laid them all out on the dining table. On the one hand I have enough meters to keep me going for a long, long time. On the other, one of the stall-holders told me about something called Hamvention, which is held in Dayton, Ohio, each May (**http://bit.ly/1A78Mvf**). Apparently, this is the biggest Hamfest in the known universe – so big that you have to book your hotel room well in advance. A crowd of my chums are planning a road trip there in May 2015 (yes, I've already booked my room!).

Creating a Vetinari clock

So, what sort of projects might one use these meters for? Well, my friend from New Zealand – The Mighty Hamster (**http://bit.ly/1lAma9R**) – suggested a really cool idea that he said I could share (I'm going to send him a 'care package' of meters in return). Can you

imagine an antique-looking wooden cabinet with four of these meters on the front implementing a clock?

I'm envisaging a large meter to represent the hours from 1 to 12; two medium-sized meters to display the minutes and seconds, both from 1 to 60; and a small meter swinging back and forth like a mini-metronome ticking off the seconds. I will be running this using a microcontroller augmented with a real-time-clock (RTC) to ensure its accuracy. I'll also be using the microcontroller to generate sound effects, like a 'tick-tock' sound (plus additional effects to be discussed at a future date).

So why call this a 'Vetinari Clock'? Well, Lord Vetinari is the scary dictator of the city-state of Ankh-Morpork in Terry Pratchett's Discworld book series. The clock in Vetinari's waiting room keeps accurate time overall, but it sometimes ticks and tocks out of sync: 'tick-tock, tick-tock… tick-tock-tick… tock…' In fact, it occasionally misses a tick or tock altogether. According to the books, the result is somewhat discombobulating. What can I say? If something is good enough for a patrician of Ankh-Morpork, it's certainly good enough for yours truly.

I'm ashamed to say I was gloating when I saw how many meters I'd acquired

Last, but not least, I will be powering my Vetinari Clock using an Arduino, but you could use any microcontroller of your choice. (I will be making all of my design and code files available for everyone to play with.) Speaking of which, in my next blog I will be discussing the various types of meters you might run across (eg, voltage, current, resistance) and the ways in which you can drive them with your microcontroller. Until next time, have a good one!

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The book applies to Windows 8.1, Windows 8.1 Pro and the vast majority of Windows 8.1 Enterprise. Also parts of the book should be applicable to windows RT 8.1 which is built on the same foundation as Windows 8.1 but is a restricted version designed specifically for ARM tablets.

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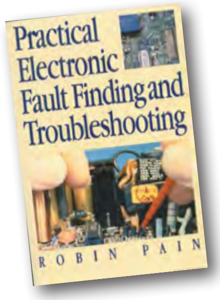

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All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

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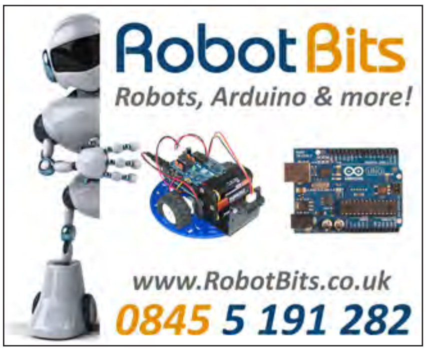

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Next Month

PortaPAL-D

With battery operation, high efficiency loudspeakers and a class-D amplifier, the *PortaPAL-D* PA system has enough power to blow your socks off! It's ideal for busking, sports events, meetings or anywhere you need a powerful, portable PA.

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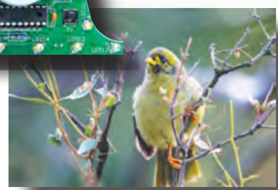
Looking for a great school project or a really unique Christmas decoration? This *Electronic Bellbird* mimics the musical bell-like sounds of a real Bellbird (or Bell Miner) and has a dynamic LED chaser display as well.



SiDRADIO – Part 3

After the hardware covered in Parts 1 and 2, next month we turn to the software behind the software-defined radio – from installation to set up and use. In particular, we'll look at SDR#, an easy-to-use software application designed to turn almost any PC into a powerful SDR using a DVB-T dongle.

Make Your Own PCBs – Part 4

Next month, Mike Hibbett wraps up the PCB series by taking a closer look at surface-mount board layout. Using the *Drum Kit Controller* as an example, he'll ship it out to a PCB manufacturer for the creation of a panel of boards.

DECEMBER '14 ISSUE ON SALE 6 NOVEMBER 2014

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